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COMET INTERCEPTOR

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THE BATTLE TO SOLVE THE GREATEST MYSTERY IN SCIENCE

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What living off-Earth will do to our brains

Happiness
Are our late 40s really the most miserable time of our lives?

CES report
We preview the year's weird and wonderful tech

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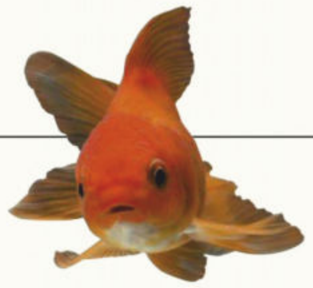

Do fish ever get bored in fish tanks? →p89

FROM THE EDITOR

Where does consciousness come from? It's the big, unanswered question at the heart of psychology. We have a picture of how our brain senses the world around it, how it creates and recalls memories and how emotions take shape. But ask a psychologist what makes us self-aware, and you'll get different answers depending on who you ask. Some say it's an illusion, others say it's a by-product of our brain's mechanics, and some even think consciousness could be the result of quantum physics.

The wide-ranging nature of these theories, and indeed the slippery nature of consciousness itself, makes things tricky. That's why one institution has created what, from the outside, looks like a science Battle Royale. A dozen or so theories will go head-to-head, in what's called adversarial collaboration. In this format, teams run mutually-agreed-upon experiments that will ultimately support one theory and disprove the other. There's no medal ceremony, but one side will concede to the theory that better fits the data. By the end of the process, we will hopefully be left with just a few options, and we might finally close in on what exactly makes us conscious. Discover the full, mind-bending story on p52.

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

The Touch Test
Launched last month by Claudia Hammond (pictured) on BBC Radio 4, *The Touch Test* is a survey commissioned by the Wellcome Collection that will explore attitudes towards physical touch and help researchers understand the role that the sense plays in health and wellbeing. To join in, take the online questionnaire at **touchtest.org**

The Curious Cases Of Rutherford & Fry
Back for their 15th series, geneticist Adam Rutherford and mathematician Hannah Fry answer questions from curious listeners. In episode one, they find out the origin of gold.
BBC Radio Four, Wednesdays at 9:30am and 8:45pm

Nature Table
A comedic celebration of all things natural history, featuring staff, stories and animals from London Zoo. Sue Perkins adds fun and frivolity to flora and fauna.
BBC Radio Four, Mondays at 6:30pm

COVER: VICTOR SOMA THIS PAGE: GETTY IMAGES, BBC X2

CONTRIBUTORS

STUART CLARK
Last year a mysterious object visited us from another solar system. Astronomy journalist Stuart investigates the mission that could get us a closer look if such an object passes by again. → p68

DR ELISA RAFFAELLA FERRÈ
With commercial spaceflight on the horizon, researchers are racing to discover what living off Earth might do to our brains. Psychologist Elisa explains what her experiments on the Vomit Comet reveal about the impact of gravity on our cognition. → p58

HAYLEY BENNETT
Commercial fishing is bad for the environment, so what would happen if we banned it entirely? Science writer Hayley investigates. → p75

ROB BANINO
How do you prepare for space exploration? Simple: you recreate the conditions on Earth, as science journalist Rob finds out. → p44

CONTACT US

Advertising
sam.jones@immediate.co.uk
0117 300 8145
Letters for publication
reply@sciencefocus.com
Editorial enquiries
editorialenquiries@sciencefocus.com
0117 300 8755
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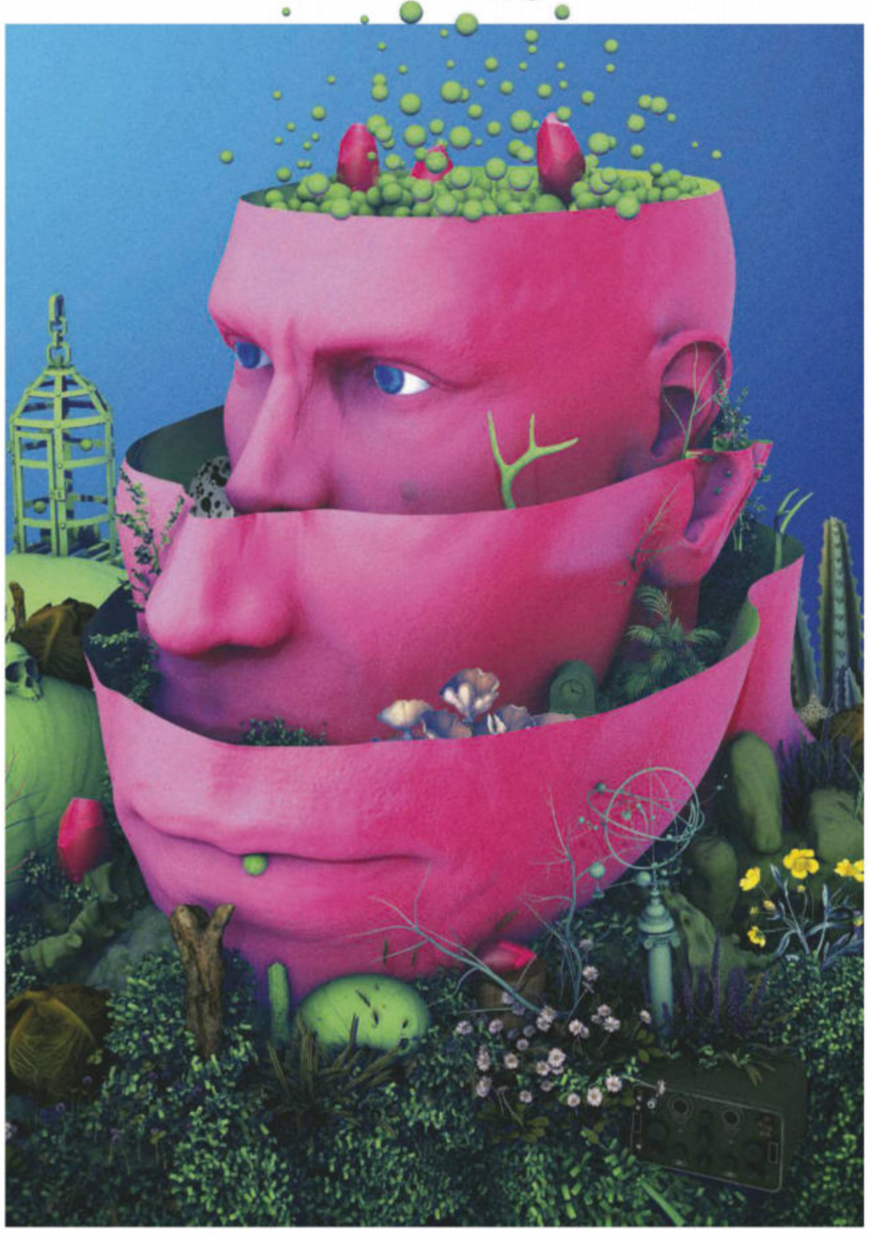

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INTERVIEW: DR ELISA RAFFAELLA FERRÈ

> "WEIGHTLESSNESS IS THE BEST THING EVER. IT'S AWE AND FREEDOM. MOVEMENTS ARE WITH NO EFFORT, NO PHYSICAL CONSTRAINTS. IT'S AN AMAZING EXPERIENCE"

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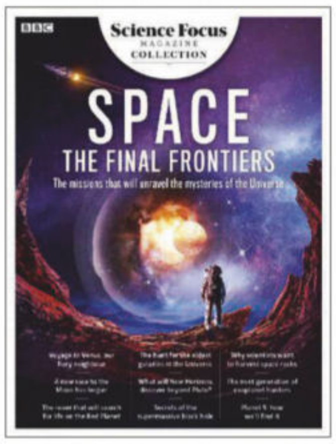
SPECIAL ISSUE



SPACE THE FINAL FRONTIERS

In this special edition, brought to you by the team at *BBC Science Focus*, discover the missions that will unravel the mysteries of the Universe, including the hunt for the enigmatic Planet 9, life on Mars, black holes, oldest galaxies and the next space race.

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EYE OPENER

Quest for camel-lot

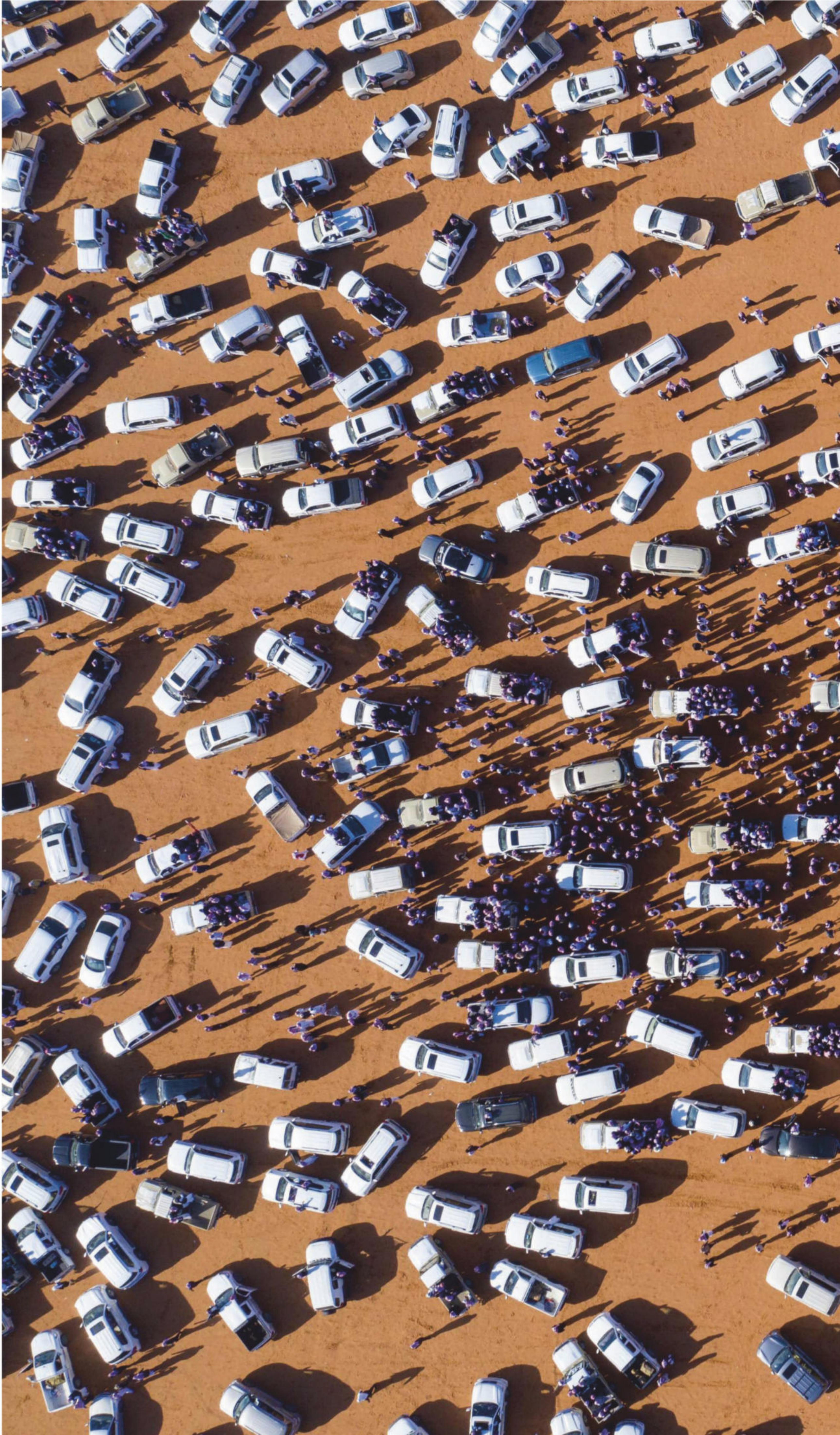
RUMAH, SAUDI ARABIA

Eager buyers surround a herd of camels in the Ad-Dahnā desert of Saudi Arabia, during the annual King Abdulaziz Camel Festival in Rumah.

Camel racing and the 'Miss Camel' beauty competition are highlights of the festival. A long neck, delicate ears, full lips and a shapely hump are all criteria for the most beautiful camel.

The festival was rocked with scandal in 2018 when a dozen camels were disqualified from the beauty contest due to the discovery of cosmetic enhancement – owners had injected botox into the camels' lips, to make the animals' pouts look more alluring.

Camels are a proud symbol of Saudi Arabia and the King Abdulaziz Camel Festival is the world's largest, and richest, camel festival. It's a sprawling six-week event for the country's elite, with prize-winning camels fetching up to one million riyals (£203,900).



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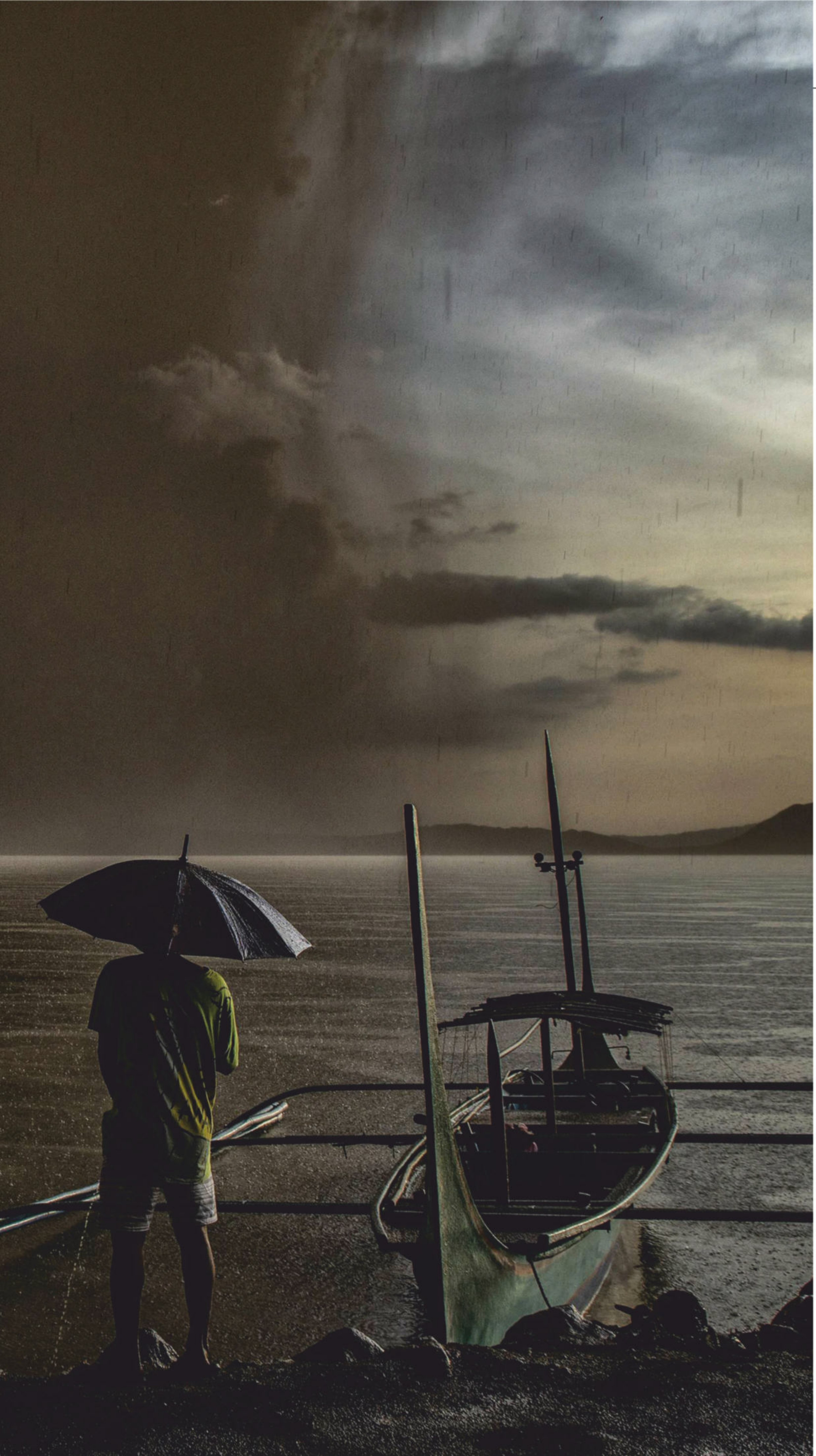

EYE OPENER

Nature's fury

TAAL VOLCANO,
THE PHILIPPINES

Residents use umbrellas to shield themselves from falling ash, as the Taal volcano blasts a plume high into the atmosphere on 12 January 2020. This steam-driven eruption belched a torrent of hot ash and gas 14km above Taal Lake, smothering nearby towns and farms.

Taal lies along the seismically active Ring of Fire in the Pacific. "That plume is a mixture of rock, minerals and volcanic glass," volcanologist Jazmin Scarlett explains. "Without adequate protection, residents risk eye irritation and respiratory issues from breathing in the ash."

Since this photo was taken, Lake Taal – the large volcanic caldera pictured here – has been almost entirely obliterated, the water vaporised by an immense amount of energy. "Generally, most crater lakes naturally recharge over time due to groundwater and rainfall, however, it does depend on the volcano," Scarlett adds.

GETTY IMAGES

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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Avenue, Bristol, BS1 4ST

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LETTER OF THE MONTH

In the first issue of 2010, we made predictions about what life in 10 years' time would be like. You can read the article at **bit.ly/2020_world** Freya Whiteford was 12 when she stashed away a copy of the magazine, and in January 2020 she took to Twitter to reveal how accurate we were.

BBC SCIENCE • TECHNOLOGY • FUTURE
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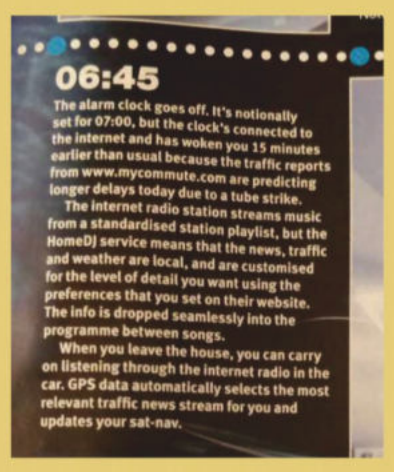
Q&A How did dinosaurs get so big?
WHY JAMES GETS THE BEST JOBS
AMAZON KINDLE KILLERS
WIN
2020 VISION
See your life in 10 years' time
Planet Pinball
Get me out of here!
Firestorm

“Admittedly pretty spot on – if you told 12-year-old me that the Freya of today has never owned a TV, she’d wonder where I went wrong.”



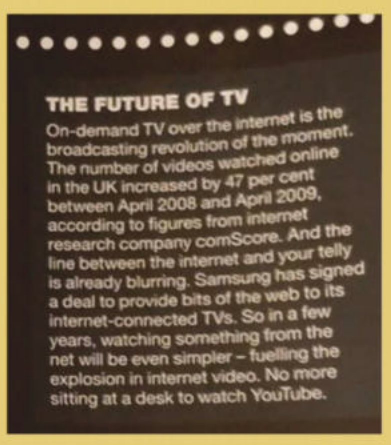
06:45

The alarm clock goes off. It's notionally set for 07:00, but the clock's connected to the internet and has woken you 15 minutes earlier than usual because the traffic reports from www.mycommute.com are predicting longer delays today due to a tube strike.

The internet radio station streams music from a standardised station playlist, but the HomeDJ service means that the news, traffic and weather are local, and are customised for the level of detail you want using the preferences that you set on their website. The info is dropped seamlessly into the programme between songs.

When you leave the house, you can carry on listening through the internet radio in the car. GPS data automatically selects the most relevant traffic news stream for you and updates your sat-nav.

“Customised travel data isn’t at all a bad shout, but in the real 2020 I just get push notifications on my phone about Glasgow traffic to me, noted pedestrian.”



THE FUTURE OF TV

On-demand TV over the internet is the broadcasting revolution of the moment. The number of videos watched online in the UK increased by 47 per cent between April 2008 and April 2009, according to figures from internet research company comScore. And the line between the internet and your telly is already blurring. Samsung has signed a deal to provide bits of the web to its internet-connected TVs. So in a few years, watching something from the net will be even simpler – fuelling the explosion in internet video. No more sitting at a desk to watch YouTube.

Freya Whiteford (@rooksoup), *via Twitter*

WRITE IN AND WIN!

The writer of next issue’s *Letter Of The Month* wins a Voyager 8200 Bluetooth headset. With active noise-cancelling, you’ll be able to block out any distractions so you can work, travel or snooze in peace while listening to your favourite music and podcasts. **plantronics.com**

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Old hat?

Reading ‘Why positivity is overrated’ (December, p77) I was suddenly reminded of the poem *IF* by Rudyard Kipling written in 1895. The second verse goes: “If you can dream – and not make dreams your master;
If you can think – and not make thoughts your aim.” There you have, in a couple of lines, what has taken Dr Gabrielle Oettingen 20 years of research to discover. Perhaps the good doctor should read more poetry? Kipling was well aware of this 125 years ago. Makes you think, doesn’t it?

George Ford, Durham, *via email*

Live fast

I’ve been reading Dr Michael Mosley’s column for some time and find it fascinating. I also recently read his book, *The Fast Diet*, which blew my mind. I’ve been following a Time Restricted Eating (TRE) schedule for a few months – six days only eating in a four-hour window, and on the seventh day I can eat whatever, whenever. I was amused when I read in Michael’s January column (p62) about the TRE study published recently, which involved a 10-hour window – “Man up!” I thought ;)

My question is, what is the optimal TRE schedule? In an ideal world, should we eat a single meal per day? Or one 14,000 calorie meal every seven days with nothing in between?

Ben Jones, *via email*

When it comes to ‘optimal’, it’s a matter of what you can stick to. I asked Prof Satchin Panda, the scientist at the Salk Institute, who has done the pioneering science on TRE, and he favours a 14-hour fast, 10-hour eating period. Evidence suggests it’s better to have most of your calories earlier in the day – he has dinner at 6pm, finishes eating by 6:30pm and doesn’t eat again until 8:30am.

Dr Michael Mosley, BBC Science Focus *columnist*

Universally speaking

In the December issue, physicist Fay Dowker explained four-dimensional space-time (p74). Has anyone ever created an experiment where the three physical directions are not changing, only time? To do this you would presumably have to be compensating for the movement of the Earth, the Solar System, the Galaxy and, maybe, the expansion of the Universe?

Tim Bates, *via email*

Cosmologically speaking, there is no such thing as ‘staying still’. You can only define something as moving relative to something else, and in fact this is fundamental to our understanding of physics: many physical laws rely on the idea that there is no special point in the Universe where you can stand and be ‘still’ with everything else moving around you. So yes, you can create an experiment that stays still but changes in time, but only if you accept that it won’t look still to someone standing on the Moon.

Sara Rigby, BBC Science Focus *online assistant*

Oops…

In the January issue (p87), we said that 57,000 hermit crabs had been killed. This should have been 570,000.

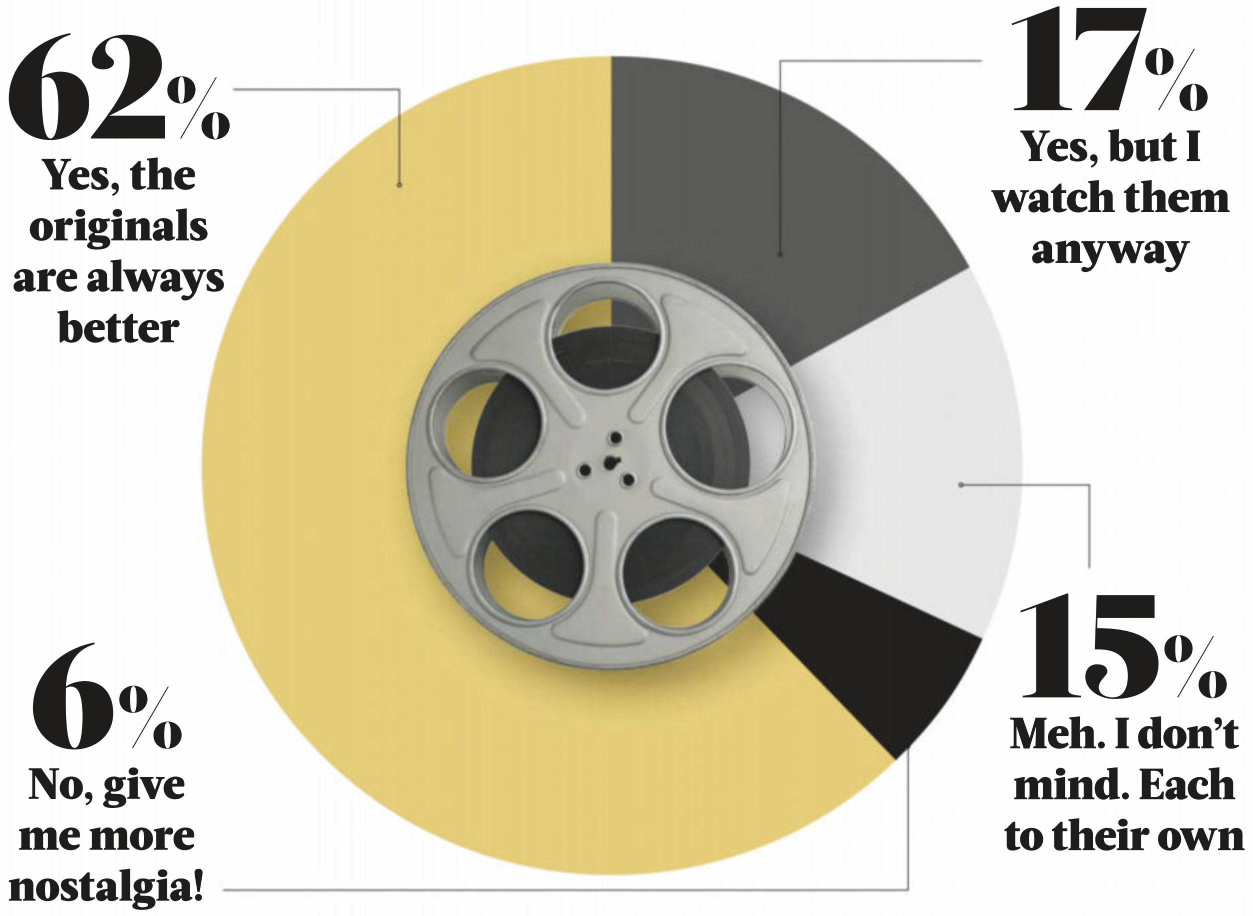
> *“WE SPOT THE MOON FROM EARTH ALMOST EVERY NIGHT. CAN YOU IMAGINE HOW BEAUTIFUL IT MIGHT BE SEEING OUR PLANET FROM THERE?”*
>
> DR ELISA RAFFAELLA FERRÈ, p58

READERS’ BUZZ

Your views on the burning science topics of the month

In last month’s *Reality Check* (p36) we asked why the past looks so rosy, and if too much nostalgia could blind us to new experiences. But we also wondered whether everyone was fed up with the stream of reboots and spin-offs of much-loved films. So we headed over to Twitter to ask our followers:

ARE YOU FED UP OF THE REMAKES, PREQUELS AND SPIN-OFFS THAT SEEM TO DOMINATE OUR SCREENS?



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THE TEAM

EDITORIAL
Editor Daniel Bennett
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Staff writer James Lloyd
Editorial assistant Amy Barrett
Production assistant Holly Spanner
Online editor Alexander McNamara
Online assistant Sara Rigby
Science consultant Robert Matthews

ART
Art editor Joe Eden
Deputy art editor Steve Boswell
Picture editor James Cutmore

CONTRIBUTORS
Scott Balmer, Rob Banino, Ovadio Benishu, Hayley Bennett, Peter Bentley, Dan Bright, Marnie Chesterton, Stuart Clark, Charlotte Corney, Andrew Cotterill, Emma Davies, Alexandra Franklin-Cheung, Alice Gregory, Dr Hilary Guite, Alastair Gunn, Adam Hylands, Christian Jarrett, Aleks Krotoski, Bill McGuire, James Minchall, Michael Mosley, Helen Pilcher, Jason Raish, Tom Redfern, Andy Ridgway, Alom Shaha, Helen Scales, Victor Soma, Jocelyn Timperley, Luis Villazon.

ADVERTISING & MARKETING
Group advertising manager Tom Drew
Advertisement manager Sam Jones 0117 300 8145
sam.jones@immediate.co.uk
Business development manager Dan Long
daniel.long@immediate.co.uk
Brand sales executive Laura Ferryman
laura.ferryman@immediate.co.uk
Newstrade manager Helen Seymour
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing
Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

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International partners manager Anna Brown

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Production director Sarah Powell
Production coordinator Emily Mounter
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Stephen Davies
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EDITORIAL COMPLAINTS
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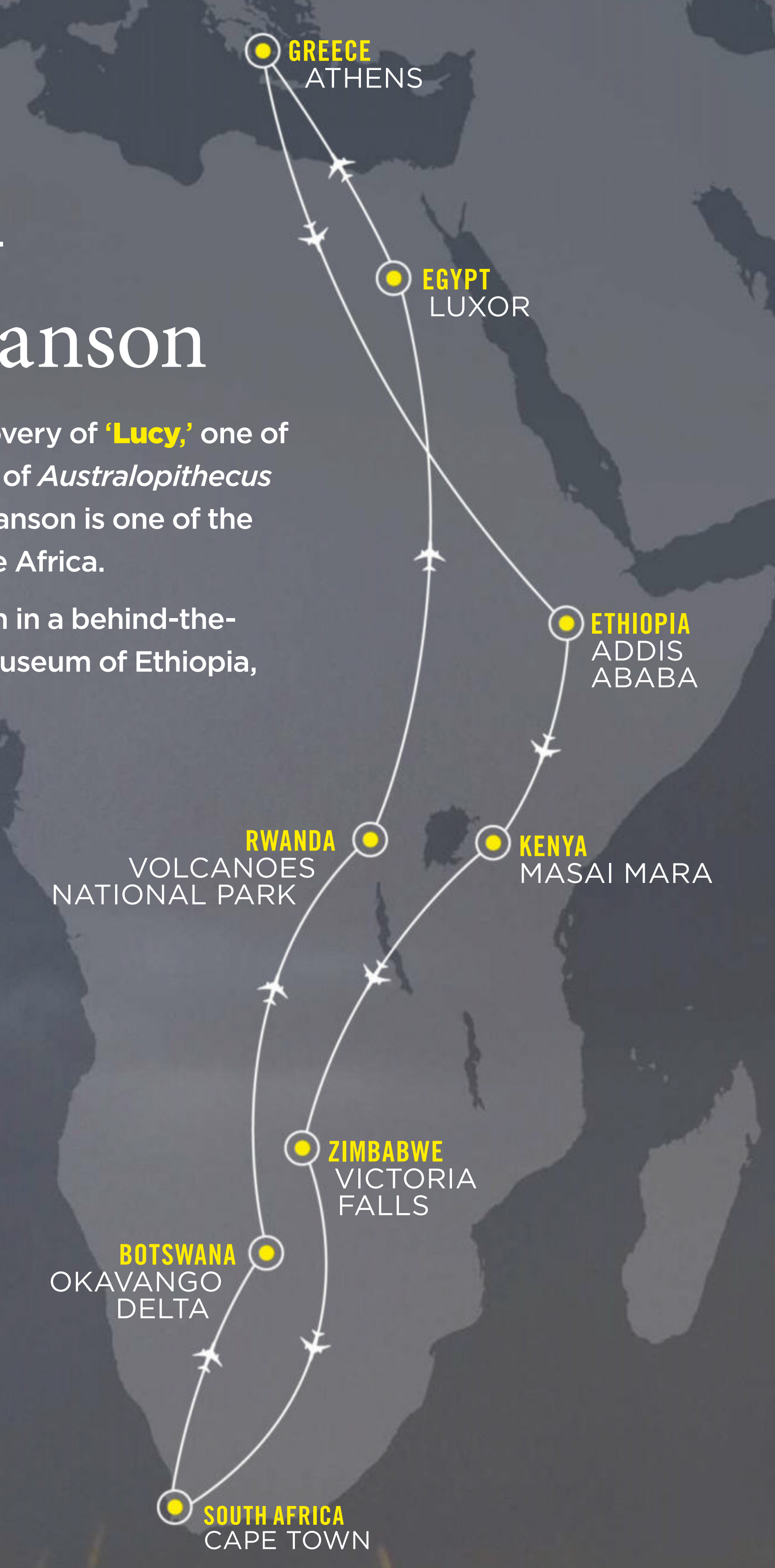
TRAVEL WITH EXPEDITION HOST

Donald Johanson

Best known for his 1974 discovery of **'Lucy,'** one of the most complete skeletons of *Australopithecus afarensis* known, Donald Johanson is one of the expedition hosts of Incredible Africa.

View the actual Lucy skeleton in a behind-the-scenes tour of the National Museum of Ethiopia, led by Donald Johanson.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SOUTH AFRICA
CAPE TOWN

Catalog N°.	AL 288-1
Common name	Lucy
Species	*Australopithecus afarensis*
Age	3.2 million years
Place discovered	Afar Depression, Ethiopia
Date discovered	November 24, 1974
Discovered by	Donald Johanson

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HAIRY ISSUE
Chill out! Stress really does turn your hair grey **p20**

CAT AND MOUSE
Cat parasite makes mice generally more anxious **p17**

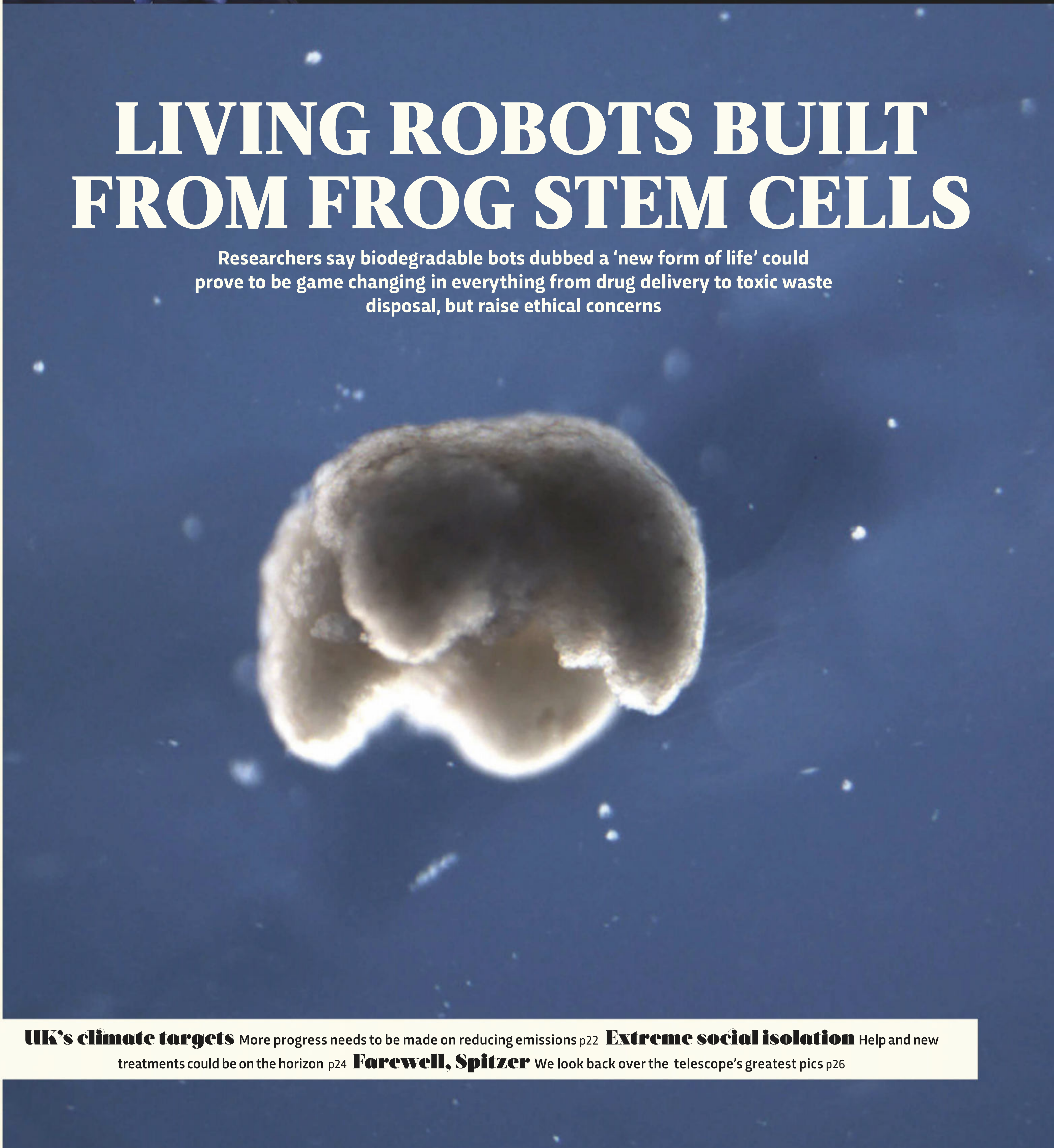
DRINK UP
New drink could beat antibiotic resistance **p18**

RHINO HOPE
Endangered northern white rhino could be saved **p20**

DISCOVERIES

LIVING ROBOTS BUILT FROM FROG STEM CELLS

Researchers say biodegradable bots dubbed a 'new form of life' could prove to be game changing in everything from drug delivery to toxic waste disposal, but raise ethical concerns



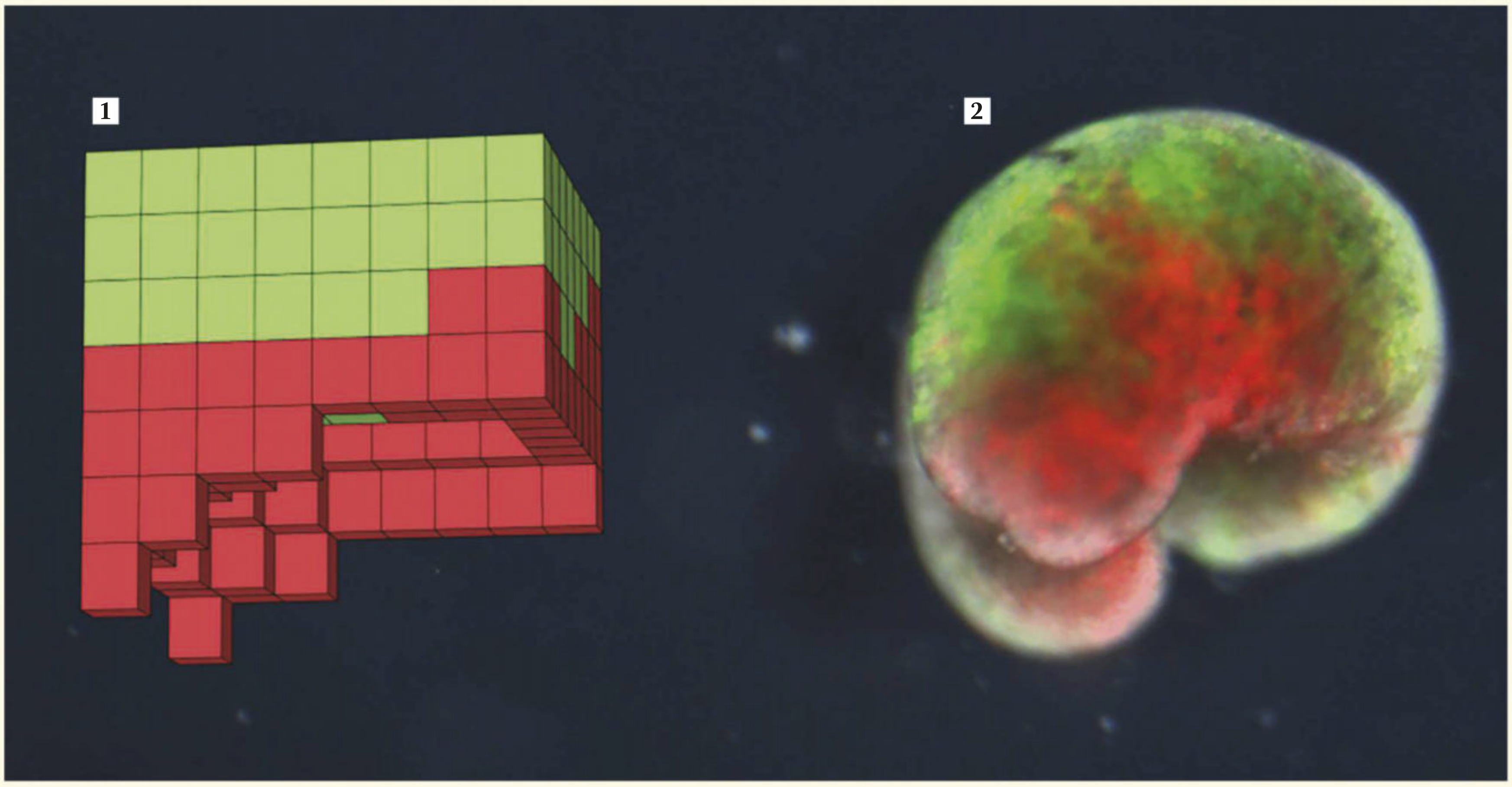
SAM KRIEGMAN/DOUGLAS BLACKISTON X2, GETTY IMAGES X2

UK's climate targets More progress needs to be made on reducing emissions p22 **Extreme social isolation** Help and new treatments could be on the horizon p24 **Farewell, Spitzer** We look back over the telescope's greatest pics p26

News in brief

PEOPLE ON LOW-INCOMES HAVE WORSE HEALTH NOW THAN PREVIOUS GENERATIONS

Despite improvements in healthcare, the poorest in society have more long-term conditions now than those who were born 100 years ago, a study at University College London has found. Using data from a pre-existing survey of 200,000 people aged 30 to 59 in England, researchers determined that the inequality between the health of the poorest and the richest had increased over the years. They compared the health of people born in 1920-22 with those born 1968-70 and found that long-term illnesses had grown twice as prevalent in low-income women, and one and a half times as prevalent in low-income men.



1 One of the frogbot designs discovered by the evolutionary algorithm

2 The physical organism, built completely from biological tissue (red for heart cells, green for skin cells)

A team of scientists based in the US have transformed stem cells taken from frog embryos into living robots. These millimetre-wide globs can move towards a target, pick up a payload such as a medicine that needs to be taken to a specific place inside a patient, and even heal themselves after being cut.

Dubbed 'xenobots', the new life forms were designed using a supercomputer by scientists at the University of Vermont and then assembled and tested by biologists at Tufts University.

"These are novel living machines," said research co-leader Prof Joshua Bongard, of the University of Vermont's Morphology, Evolution & Cognition Laboratory. "They're neither a traditional robot nor a known species of animal. It's a new class of artifact: a living, programmable organism."

The team at Vermont used the Deep Green supercomputer cluster to run an evolutionary algorithm that was given a simple task to achieve, such as locomotion in one direction, to create thousands of potential designs for the new life forms. Any failed designs were ruled out, while the more promising ones were refined further. The most successful designs were selected for testing by the team at Tufts.

> "They're neither a traditional robot nor a known species of animal. It's a living, programmable organism"

The Tufts team harvested heart and skin stem cells from the embryos of African clawed frogs, *Xenopus laevis*, and used tiny forceps to arrange them into the designs specified by the computer modelling work. As heart cells can expand and contract, they acted as tiny motors to enable the newly created organisms to move around in their environment. In later tests, the xenobots were able to move in circles, push pellets into a chosen location, and carry around a small payload in a specially designed pouch. They were also able to self-heal after being cut.

The xenobots could be put to a number of uses, such as cleaning up pollution from the oceans, or targeted drug delivery systems. Though the work is still at a relatively early stage, the researchers say they are aware of the ethical questions that could arise in the future, particularly if the xenobots' cognitive abilities are increased.

"If humanity is going to survive into the future, we need to better understand how complex properties, somehow, emerge from simple rules," said Prof Michael Levin, the director of the Center for Regenerative and Developmental Biology at Tufts. "I think it's an absolute necessity for society going forward to get a better handle on systems where the outcome is very complex," he added.

PACKED SCHOOL LUNCHES LACK NUTRITION

Fewer than two in every 100 packed lunches eaten by children in English primary schools meet nutritional standards, according to a study at Leeds University. The team compared the nutritional quality of packed lunches brought into a sample of primary schools in 2006 and then again in 2016. Although they found the amount of sugary food included has dropped slightly, the majority of children still eat crisps regularly and just one in five had vegetables in their packed lunches. Over the same period, eight standards have been introduced for cooked school lunches, including restrictions on sweets, snacks and fizzy drinks, and minimum requirements on the amount of vegetables, protein and dairy in each meal. Packed lunches, however, are not subject to any control.

In numbers

5 DAYS

The time it takes a UK resident to create the same amount of carbon emissions a person in Rwanda generates each year.

10 YEARS

The amount by which maintaining habits like exercise and good diet can boost healthy life expectancy.

20 MILLION

The number of trees the National Trust plans to plant over the next decade.

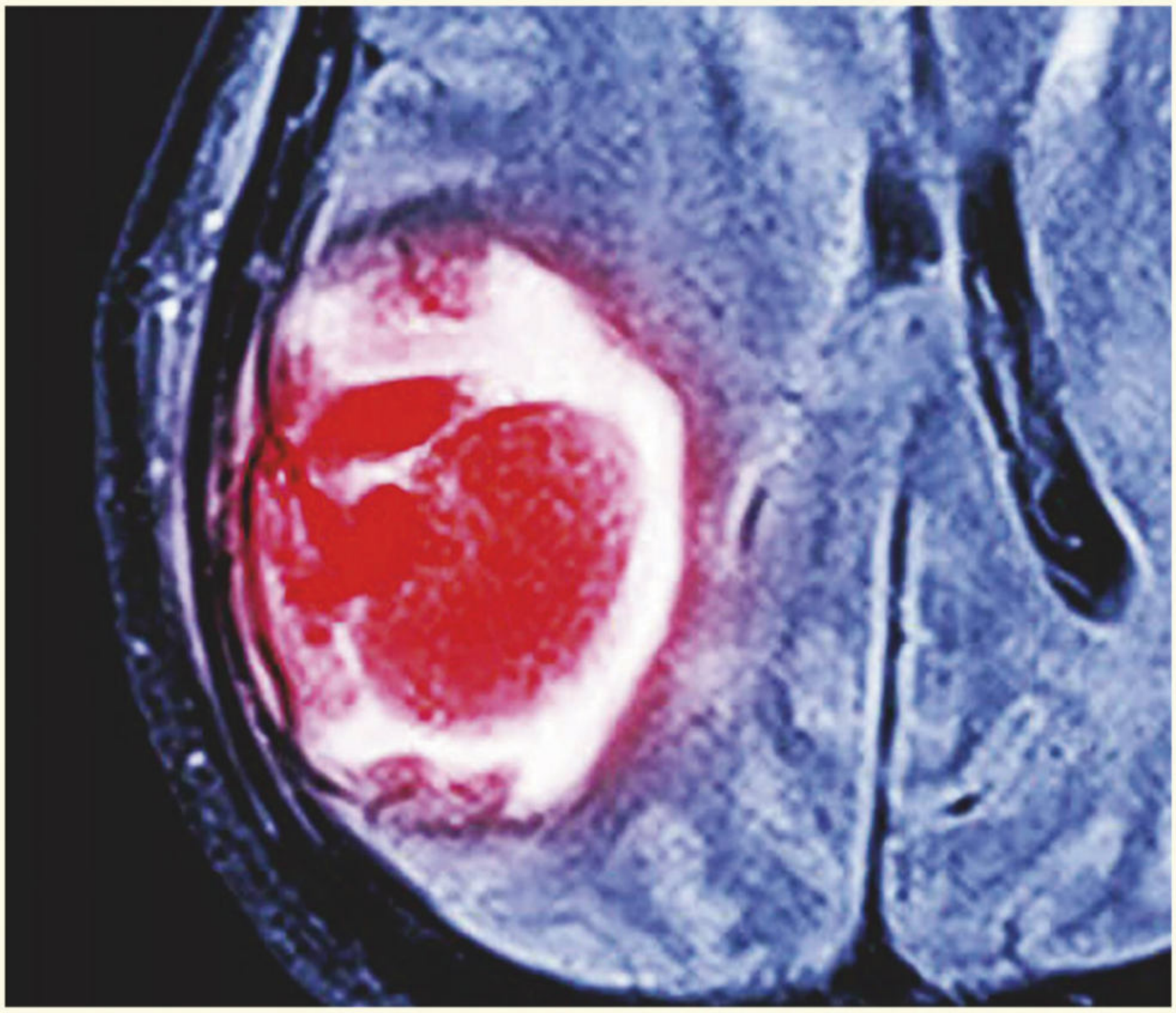
MEDICINE

Robots trained to spot brain tumours faster than humans

Scientists at New York University have developed and trained an artificially intelligent system that can diagnose brain tumours faster and more accurately than human doctors.

The AI generated an accurate brain tumour diagnosis in less than 150 seconds, compared to 20 to 30 minutes by a pathology lab. According to the research, which was published in the journal *Nature Medicine*, the AI-based diagnosis was 94.6 per cent accurate, compared to 93.9 per cent for human doctors. "With this imaging technology, cancer operations are safer and more effective than ever before," said senior author Dr Daniel A Orringer, associate professor of neurosurgery at NYU Grossman School of Medicine, who co-led the study.

Using the new technique, brain tumour biopsies could be taken from patients and analysed straight away during an operation, therefore streamlining and improving cancer diagnosis.



Scan of a brain showing a tumour (in red)

ALTRUISTS

Helping others can reduce pain, researchers from Peking University have found. They found that blood donors reported less pain than those undergoing blood tests. They also found that people could hold their hands in icy water for longer if they were told it was to benefit science.

TEA DRINKERS

Drinking tea at least three times a week is linked with a healthier life, a team at the Chinese Academy of Medical Sciences found. Their study of more than 100,000 people found that tea drinkers had a 20 per cent lower risk of incident heart disease and stroke, and a 15 per cent decreased risk of all-cause death.

Good month

Bad month

IMAGE-OBSESSED MEN

Young men taking anabolic steroids in an attempt to get the ripped physiques popular on social media and reality TV shows could cause a strain on the NHS in coming decades, says a report by UK Anti-Doping. Steroid abuse can damage organs and increase the likelihood of heart disease and stroke, the researchers say.

MOVIE SUPERFANS

Sometimes it really is better to manage your expectations. A study by researchers at Ohio State University found that viewers of *Star Wars VIII: The Last Jedi* film who went in with high expectations but were disappointed enjoyed it significantly less than those going in with lower expectations.

ALAMY, GETTY IMAGES ILLUSTRATIONS: TOM REDFERN

Rather unfairly, the *Toxoplasma gondii* feline parasite doesn't tend to have an effect on cats, but it will make their prey more foolhardy

ZOOLOGY

Cat parasite makes infected mice generally less anxious

It's been known for some years that when the cat parasite *Toxoplasma gondii* infects rodents it causes them to lose their fear of feline predators, making them easier to catch, and so allowing the parasite to complete its life cycle within cats.

However, according to new research carried out by a team at the University of Geneva, the effect of *T. gondii* is wider in reach and actually leads to infected mice showing a decrease in general anxiety and a reduced aversion to a broad range of threats – not just cats.

They found that mice infected with the parasite for at least five weeks were more likely to explore novel environments, interact with the hands of the researchers, and investigate the odours of bobcats, foxes and guinea pigs than their more skittish, uninfected counterparts.

To investigate what was going on, the team used a cutting-edge imaging system to accurately map the distribution, size and number of cysts caused by *T. gondii* in the brains of the infected mice. They found particularly high concentrations of cysts in regions involved with processing visual information, along with high levels of inflamed neural tissue throughout the brain.

"For 20 years, *T. gondii* has served as a textbook example for a parasitic adaptive manipulation, mainly because of the specificity of this manipulation," said Prof Ivan Rodriguez, a co-senior author of the study. "We now show that the behavioural alteration does not only affect fear of feline predators but that major changes occur in the brain of infected mice, affecting various behaviours and neural function in general."

The researchers now plan to further examine how neuroinflammation can alter a range of behavioural traits such as anxiety, sociability or curiosity.

WASHING ON COOL CYCLES IS BETTER FOR THE ENVIRONMENT

Switching to a quicker, cooler washing cycle will help reduce the plastic pollution problem and make your clothes last longer, a UCL study has found. Hundreds of thousands of microfibres – tiny synthetic strands that account for more than a third of all plastic reaching the ocean – are flushed down the drain with every load of washing, where they can travel to beaches and oceans before being swallowed by sea creatures. Researchers compared 30-minute cycles at 25°C with 85-minute cycles at 40°C and found there was up to 74 per cent less dye release and up to 52 per cent less microfibre release with the cool wash.

They did what?

Lego blocks supercooled

WHAT DID THEY DO?

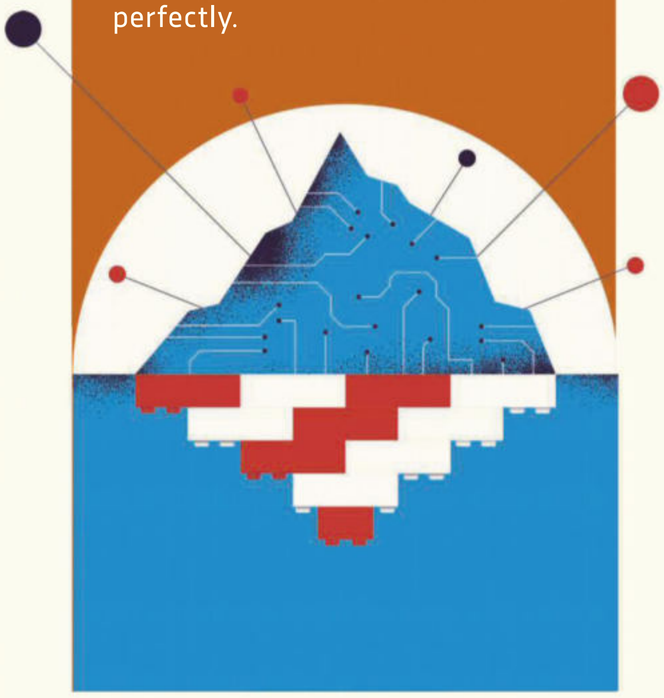
A team of ultra-low temperature physicists at Lancaster University put four Lego blocks into the world's most effective refrigerator.

WHAT DID THEY FIND?

They managed to cool the Lego blocks down to -273.13°C, which is just 1.6 millidegrees above absolute zero.

WHY DID THEY DO THAT?

Both superconductors and quantum computers need extremely low temperatures to function. This requires the use of materials that transfer heat as slowly as possible in order to maintain the low temperatures for as long as possible. It turns out that the plastic used to make Lego blocks, combined with their unique interlocking shape, fits this bill perfectly.



HEALTH

New drink could thwart antibiotic resistance

A drink containing bacteria could become a promising new weapon in the battle against antibiotic-resistant bacteria, scientists at the University of Birmingham have found.

The drink works by targeting plasmids, which are small DNA molecules found inside bacterial cells. Plasmids frequently carry genes that give rise to antibacterial resistance in bacteria. They replicate independently, and spread between different bacteria, carrying the resistance genes with them as they go.

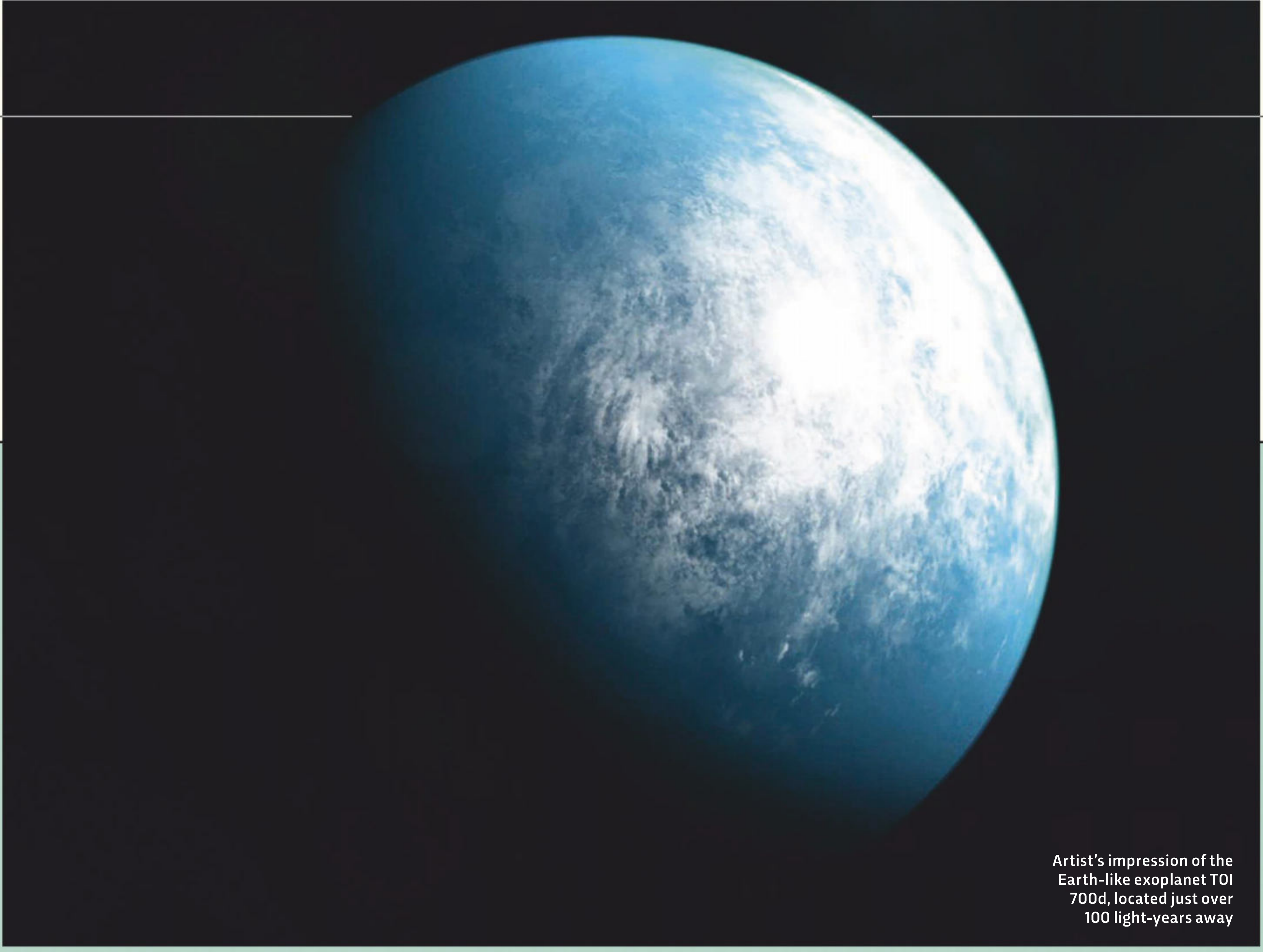
> "The drink has potential to work against many resistant bacteria found in the gut"

The drink contains a new type of genetically engineered bacteria carrying what the researchers call 'pCURE plasmids'. The pCURE plasmids prevent target plasmids of resistant bacteria from replicating, and stop the resistance genes from spreading, effectively making the bacteria susceptible to antibiotics again.

"We were able to show that if you can stop the plasmid from replicating, then most of the bacteria lose the plasmid as the bacteria grow and divide," said lead researcher Prof Christopher Thomas. "This means that infections that might otherwise be hard to control, even with the most powerful antibiotics available, are more likely to be treatable with standard antibiotics."

The team is now seeking funding for a clinical trial for the drink which has potential to work against many resistant bacteria commonly found in the human gut, including *E. coli*, *Salmonella* and *Klebsiella pneumoniae*.

"This is a promising start. We aim to make modifications to further improve the efficacy of our pCURE plasmids before moving towards a first clinical trial," said Thomas. "Antibiotic resistance is one of the biggest medical challenges of our time. We need to be tackling this on a number of different fronts, including by reducing our use of antibiotics and searching for new, more effective drugs. Our approach, which tackles one of the causes of antimicrobial resistance at a genetic level, could be an important new weapon in this battle."


Artist's impression of the Earth-like exoplanet TOI 700d, located just over 100 light-years away

SPACE

TESS has found its first planet within the Goldilocks zone

The Transiting Exoplanet Survey Satellite spotted the planet just over 100 light-years away

NASA's Transiting Exoplanet Survey Satellite (TESS) has spotted its first potentially habitable planet in a star's 'Goldilocks zone', where conditions are just right to allow the existence of liquid water and therefore life.

Named TOI 700d, the planet is the latest in a handful of potentially habitable Earth-sized worlds found throughout the Galaxy. It is around 20 per cent bigger than Earth, completes its orbit every 37 days and receives 86 per cent of the energy from its star that the Sun provides to Earth.

It is the outermost planet found in orbit around the star TOI 700, which is a small, cool, dwarf star located just over 100 light-years from Earth in the southern constellation Dorado. TOI 700 is roughly 40 per cent of the Sun's mass and size, and about half its surface temperature.

"TESS was designed and launched specifically to find Earth-sized planets orbiting nearby stars," said Dr Paul Hertz, astrophysics division director at NASA in Washington. "Planets around nearby stars are easiest to follow up with larger telescopes in space and on Earth. Discovering TOI 700d is a key science finding for TESS. Confirming the planet's size and habitable zone status with Spitzer is another win for Spitzer as it approaches the end of science operations this January."

TESS views large swathes of the sky, called sectors, for 27 days at a time. This long period of observation allows the satellite to monitor changes in a star's brightness caused by an orbiting planet crossing in front of its star from our perspective, an event called a 'transit'.

While the exact conditions on TOI 700d are a mystery, a team of researchers at NASA's Goddard Space Flight Center used known information, such as the planet's size and the type of star it orbits, to generate a series of computer models and make predictions. One simulation revealed an ocean-covered world surrounded by a dense, carbon-dioxide-dominated atmosphere, similar to what scientists suspect surrounded Mars when it was young. Another model depicts TOI 700d as a cloudless, all-land version of modern Earth.

"It's exciting because no matter what we find out about the planet, it's going to look completely different from what we have here on Earth," said Gabrielle Englemann-Suissa, who led the computer modelling team.

GETTY IMAGES, ALAMY, NASA/GSFC

STRESS REALLY DOES TURN YOUR HAIR GREY

Prematurely greying hair has long been considered a physical effect of suffering from stress. Now, researchers at Harvard University have found the first scientific evidence explaining exactly why this is: stress triggers nerves that are part of the fight-or-flight response, which in turn cause damage to the pigment-regenerating stem cells in hair follicles.

2008
2012
2016

ZOOLOGY

New hope for endangered rhinos

Northern white rhino embryos are ready to implant into a surrogate mother to try and save the subspecies from extinction

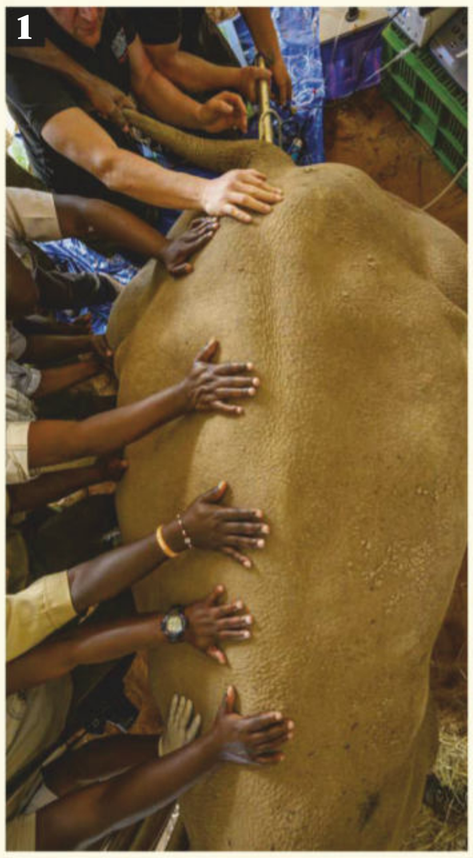
Northern white rhinos Najin and Fatu are the last of their kind. As they are both female and have no males to mate with, their species is considered functionally extinct. However, things may be about to change, thanks to the BioRescue research project, which involves an international group of researchers from Leibniz Institute for Zoo and Wildlife Research, Avantea Laboratory, Dvur Králové Zoo, Ol Pejeta Conservancy and the Kenya Wildlife Service. The team successfully harvested eggs from the two animals and artificially inseminated them using frozen sperm taken from now deceased males to create viable northern white rhino embryos for the second time, repeating a similar successful operation carried out in August 2019.

> "We are strongly committed to our plan to transfer a northern white embryo into a surrogate mother"

The animals were placed under general anaesthetic at their home in Ol Pejeta Conservancy in Kenya, before nine immature egg cells – three from Najin and six from Fatu – were harvested from the animals' ovaries using a probe guided by ultrasound. The egg cells were then transported to the Avantea Laboratory in Italy, where they were incubated using a cutting-edge desktop incubator donated by pharmaceutical company Merck. After being fertilised, one of the eggs from Fatu developed into a viable embryo and is now stored in liquid nitrogen along with the two embryos from the first procedure.

"Our repeated success in generating a third embryo from Fatu demonstrates that the BioRescue programme is on the right track," said Prof Thomas Hildebrandt, from Leibniz Institute for Zoo and Wildlife Research. "Now, the team will make every effort to achieve the same result for the 30-year-old Najin before it is too late for her. We are strongly committed to our plan to transfer a northern white embryo into a surrogate mother in 2020 to ensure the survival of the northern white rhino."

The next step is to select a suitable surrogate from the group of southern white rhinos at Ol Pejeta Conservancy. Despite the fact that more research is still needed, the team expects that a first attempt for this crucial, never before achieved step, may be undertaken in 2020.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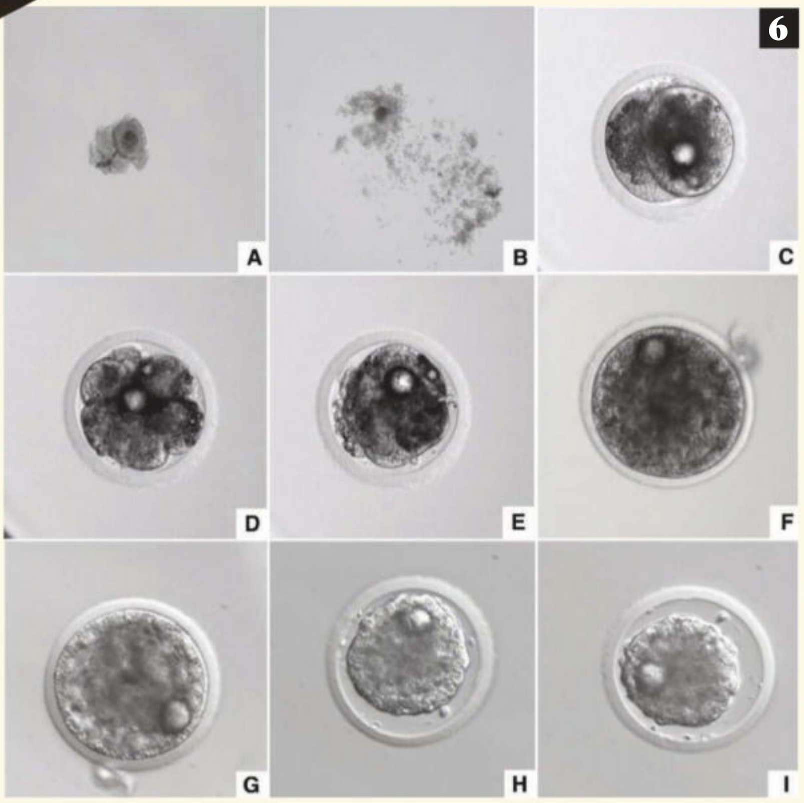
AMI VITALE X5, CESARE GALLI/AVANTEA, GETTY IMAGES X2, US GOVERNMENT/WHITE HOUSE X2

EVEN UNTRAINED DOGS RESPOND TO HUMAN COMMANDS

Here's proof even stray dogs are good boys: 80 per cent of untrained stray dogs can still understand human cues, Indian researchers have found. Studying stray dogs across several Indian cities, Dr Anindita Bhadra of research institute IISER Kolkata and colleagues found the animals successfully followed pointing directions – either momentarily or repeated – when presented with two covered bowls of food. Stray dogs are a common feature in cities around the world, particularly in developing countries, and this research could be key to understanding how humans shape stray dog behaviour. However, researchers did note that shyer, more anxious animals tended not to participate, so more work is needed to determine a potential link between the ability to understand human cues and personality traits of the dogs.

3



6

5

7

1. Vets, researchers and keepers were all on hand during the procedure
2. A sedated Najin is put in the right position
3. Eggs were collected using a probe
4. Najin recovers from the operation
5. Eggs are extracted from ovarian fluid
6. Developing embryos
7. The northern white rhino rescue team

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**

CLIMATE JUSTICE FOR ALL!
BAN FRACKING NOW!
YOUNG Friends of the Earth Scotland
Friends of the Earth Scotland

Environmental campaigners calling on Scottish politicians for greater urgency on climate change

RENEWABLES EDGE AHEAD OF FOSSIL FUELS

In 2019, Britain got more of its electricity from zero carbon sources than fossil fuels for the first time since the Industrial Revolution, new data from the National Grid shows.

Wind, solar and nuclear together delivered 49 per cent of Britain's electricity in 2019, while just 43 per cent was generated by fossil fuels. The remainder came from biomass. In contrast, 76 per cent of Britain's electricity came from fossil fuels in 1990.

"As we enter a new decade, this truly is a historic moment and an opportunity to reflect on how much has been achieved," said John Pettigrew, National Grid's chief executive.

CLIMATE

Scotland could fall short on climate targets

More progress needs to be made on reducing emissions from sectors like farming and transport

Scotland could miss its climate target if it fails to take more action to cut its emissions, its official climate advisors have said.

Last year, Scotland set itself an ambitious goal to achieve net zero greenhouse gas emissions by 2045, five years earlier than the rest of the UK. But it must now strengthen its climate change policies in order to meet the target, the Committee on Climate Change (CCC) said. "The spotlight is now on Scotland's plan to deliver meaningful reductions across all sectors of the economy, including from buildings, road transport, agriculture and land use," said Lord Deben, chairman of the CCC, which advises the UK and its devolved parliaments on climate change. "Their contribution to reducing emissions is vital to Scotland's success."

INVASIVE PLANTS IDENTIFIED

Scientists at the University of Exeter have found a new way to predict which plants are likely to take hold as invasive species. Invasive plants grow faster in the region they invade, meaning growth rate in their native range can't predict invasiveness.

But the study, which covered more than 500 plant species, looked at something else: resilience. It found that plants which easily 'bounce back' after disturbances like ploughing, flooding or drought are more likely to be invasive. "What we found was a real surprise," said co-author Prof Dave Hodgson. "Based on this finding, we should avoid the export of plant species that grow well in disturbed environments."

While Scotland has been a leader in renewable electricity and reducing emissions from waste, less progress has been made on cutting its emissions in sectors such as transport and agriculture.

REAL ACTION NEEDED

Last year, the CCC told the UK government that there is a growing gap between its climate ambition and the policies which have actually been put into place. The UK is still off track on its legally binding carbon budgets due to slow progress on transport, buildings, agriculture and land use, it said. The progress of Scotland, and the wider UK, on the climate front, is particularly significant this year since they will host the major COP26 UN climate conference in November.

Both the UK and Scotland's credibility, as president and host of the conference respectively, rest on "real action at home", the CCC said. The conference will take place in Glasgow and is seen as a key deadline for countries to raise the ambition of their goals. Current pledges put the world on track to raise global temperatures by 3°C, not the 1.5°C or "well below 2°C" that the Paris Agreement promises.

"This is the COP at which the Paris Agreement is really going to begin," said Caroline Rance, climate and energy campaigner at Friends of the Earth Scotland. "We really need Glasgow to deliver the increases in ambition that are going to close that gap to get anywhere near close to meeting that 1.5°C goal."

Scotland's First Minister Nicola Sturgeon highlighted the November summit as a key date for the year ahead in her New Year's message, saying it will give Scotland the chance to lead by example. But Rance says Scotland, and other industrialised nations, is not doing enough to tackle the climate crisis. "They're still not contributing their fair share," she says.

> **"The spotlight is now on Scotland's plan to deliver meaningful reductions across all sectors of the economy"**

INSPIRED

FRIENDLIER FISHING

Placing LED lights on fishing nets reduces the chances of turtles and dolphins being caught, according to research by the University of Exeter.

FLYING START

Over 70 experts have set out a major report to help insect recovery. Compiled by a team at the Netherlands Institute of Ecology, it details the best ways to tackle the huge decline seen in insect numbers, and contains guidelines to help farmers and urban planners boost diversity.

EXPIRED

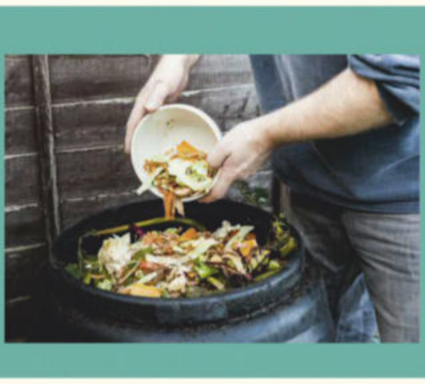
THAWING RIVERS

River ice has declined globally in the past 30 years, according to the University of North Carolina. Frozen rivers are an important means of transport at high latitudes and also help regulate greenhouse gases released into the atmosphere.

LEMURS UNDER THREAT

Ruffed lemurs, the largest species of lemur, could lose 38-93 per cent of their habitat by 2070 due to climate change and deforestation, according to the University of Massachusetts.

IT'S EASY BEING GREEN



CUT DOWN ON FOOD WASTE

According to UK charity WRAP, UK homes throw away a fifth of the food they buy, most of which is edible. As well as better meal planning, make sure you distinguish between 'use by' and 'best before'. 'Use by' dates are about safety, and food shouldn't be eaten past this date. But 'best before' dates are about quality – the food is still safe after this date, says the Food Standards Agency. Put remaining food waste in an organic waste bin rather than landfill. In landfill, it will break down to produce methane, a greenhouse gas. Consider home composting, which avoids transport impacts and produces fertiliser for your plants.

GETTY IMAGES X6, PRODELPHINUS

Dr Alan Teo associate professor of psychiatry

Horizons

New definition for *hikikomori* may help to identify and treat extreme social isolation around the globe

Hikikomori, which means 'pulling inwards' in Japanese, is a condition in which those affected withdraw from society, often not leaving their homes for days on end. It was first identified in Japan in the late 1990s but current research suggests that the condition is much more widespread than previously thought. Alan Teo, an associate professor at Oregon Health and Science University, has been researching _hikikomori_ for more than a decade. He says it's time the condition was given a clearer definition to enable more effective treatments worldwide.

WHAT IS YOUR NEW THINKING ON THE DEFINITION OF *HIKIKOMORI*?

We're trying to revise the definition of *hikikomori* based on new information, new knowledge, new science and the combined experience that I've had interacting with individuals who have it, as well as my Japanese collaborator. In a nutshell, the core feature of *hikikomori* is the sense of physical isolation in the home, whatever that home is. I think a misunderstanding that has happened among the lay population is to think of *hikikomori* only as being the most extreme. I've talked with *hikikomori* who haven't left their room, or who haven't been out of their home for many, many years. But, they are much more extreme examples.

One of the messages here is that the definition also includes milder forms of social withdrawal. Specifically, we're saying that if you only leave the home three days a week or less, we're proposing that figure to be the threshold for social withdrawal. In other words, the threshold to meet the definition of *hikikomori*.

OBVIOUSLY THE NAME'S JAPANESE, AND THAT'S WHERE *HIKIKOMORI* WAS FIRST IDENTIFIED, BUT THERE'S MORE RESEARCH COMING OUT THAT IT'S NOT A UNIQUELY JAPANESE PROBLEM, IS IT?

No, it isn't [uniquely Japanese]. That's one of the reasons why I think it's important that we've put out this new definition. There are clearly many reports of *hikikomori* from all over the world. In addition, there's more and more energy and excitement among scientists and researchers surrounding the subject. I'm getting contacted on a regular basis by researchers in France, Turkey and many other countries, who would like to study it.

One of the first steps in research is having a definition that you can operationalise. What that means is that we take a definition, and then we turn that definition into criteria that we can eaily measure. So, using that example of physical isolation that I

Hikikomori is a condition where individuals isolate themselves, but family members can help, a new study finds

ALAMY

> "We're proposing the threshold for social withdrawal to be only leaving your home three or less days in a week"

brought up as being the core criteria, it is relatively easy to measure how often a person leaves their home. And this is one of the reasons I've included this measure in the new definition. This is something that scientists across countries and in different cultures can use and apply the definition consistently.

ARE THERE ANY COMMON FEATURES AMONG PEOPLE WHO ARE AFFECTED BY *HIKIKOMORI*?

I think each person is an individual, and of course, there's lots of variation even within a culture. That said, when I listened to stories of *hikikomori*, there are some common threads.

Usually, *hikikomori* develops over an extended period of time. It isn't like a switch that just suddenly turns on. People with *hikikomori* often have had major stressors early in their life, such as bullying or academic difficulties in school. They may even have faced problems with attending school in the first place. AnF that can fester and build up over time, turning into this prolonged social withdrawal that we see.

It's likely they may also have challenges within their family relationships. So, let's say that the 16-year-old son is *hikikomori*. He may be having difficulties with his parents, or his parents may be having difficulty in how they communicate and relate to their son. So, things like that.

Conflict within the family, difficulty with school or other early traumatic experiences – it all builds up over time until it reaches this syndrome of social withdrawal.

HOW WOULD YOU RESEARCH SOMETHING LIKE THIS? IT SEEMS THAT THERE MAY BE DIFFICULTIES IN EVEN CONTACTING THESE PEOPLE IN THE FIRST PLACE…

You're hitting the nail on the head there. This has been one of the biggest impediments to moving research forward regarding *hikikomori*. But there are also other impediments to moving research forward – funding, for example. But certainly, the difficulty of reaching out and getting individuals with *hikikomori* to participate in research has been a major barrier.

There's a couple of thoughts that we have had in terms of trying to get around this. One of my interests is to do more research with family members because they are usually the first people to reach out for help. I regularly get emails out of the blue, but they're almost always from a brother, from a mother, from an aunt. Someone who says: "It is really tearing our family apart. Can you help us?" So, the family is the first point of contact, and they could be really helpful with regards to early identification.

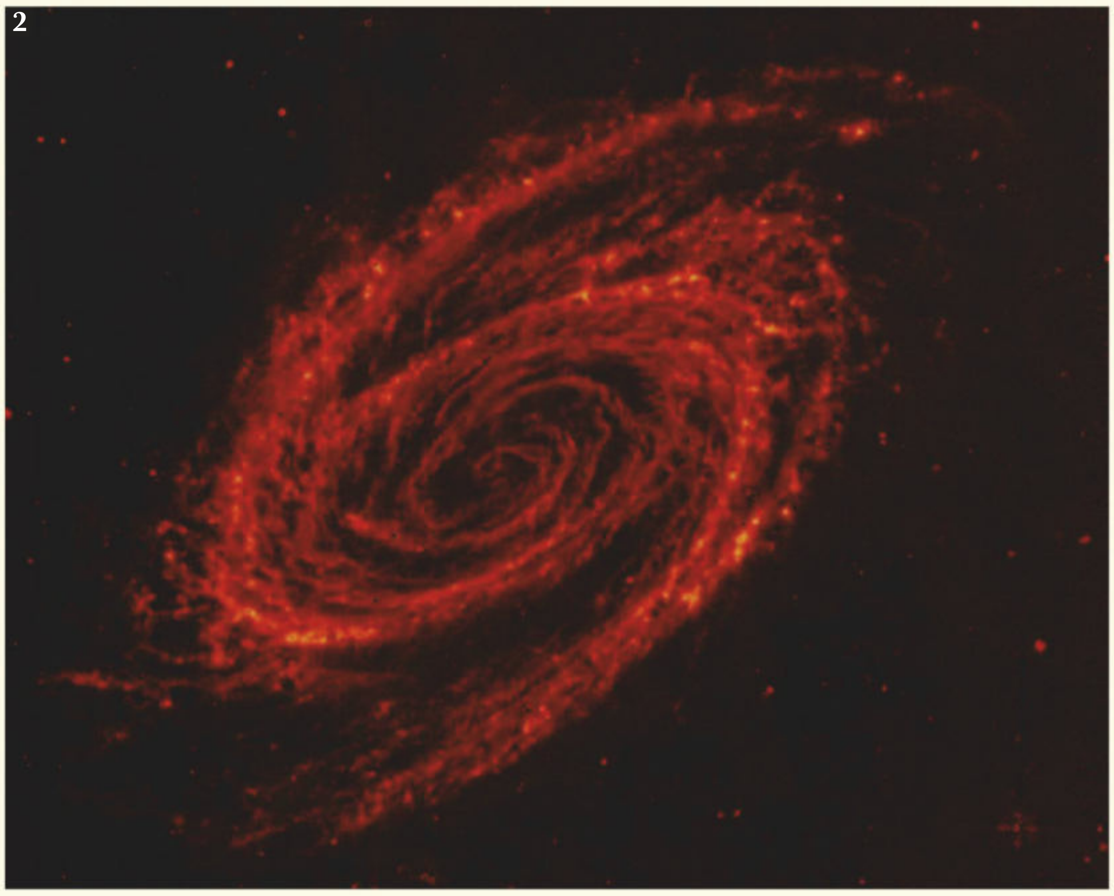
We know that there's a significant delay in terms of how long it actually takes for us to identify a case, and if family members are more engaged and can identify signs of *hikikomori* early on, then maybe we can intervene earlier and do better at treating the condition.

DR ALAN TEO
Alan is an associate professor of psychiatry at Oregon Health and Science University.
Interviewed by* BBC Science Focus *commissioning editor Jason Goodyer.

SPACE

Looking back at Spitzer's greatest hits

On 30 January 2020, NASA's Spitzer Space Telescope was retired from orbital operations. Since its launch in August 2003, Spitzer's sensitive infrared instruments have enabled it to study cold, dusty and distant objects in unprecedented detail. Here are some of its best images...



NASA/SPITZER X5

1. This view of the North America Nebula was made by combining images created using visible light (blue) and infrared (red and green). It shows clusters of young stars aged between one and five million years old.

2. The spiral galaxy Messier 81 is located 12 million light-years from Earth in the northern constellation of Ursa Major, which also includes the Plough. It is easily visible through a pair of good binoculars. This image has been specially processed to isolate the distribution of dust throughout. The dust particles are composed of silicates – chemicals that are similar to the sand you'd find on a beach.

3. The eye-like Helix Nebula is located about 700 light-years from Earth. It is a planetary nebula – an expanding shell of ionised gas that is created when the internal fuel supply of a Sun-like star runs out, leaving the outer layers to puff out. The Sun will follow a similar fate in about five billion years.

4. This image shows Messier 106, also known as NGC 4258, a spiral galaxy located 23 million light-years away from Earth. It was first discovered by the French astronomer Pierre Méchain in 1781.

5. The giant star Zeta Ophiuchi is 20 times more massive and 80,000 times brighter than the Sun. It has a huge shock wave at its fore, created by raging winds that flow from it. This infrared image shows its vast scale.

3

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5

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Coronavirus | Life in our late 40s | Australian wildfires

REVIEW

CORONAVIRUS: IS IT A CAUSE FOR PANIC?

January saw a new virus emerge in the Chinese city of Wuhan. By the end of the month it had killed over 100 people, infected thousands more and had spread to other countries. Could it be the beginning of a pandemic?

"Most of the cases have come from people with direct links to Wuhan or other local cities where the virus is known to be present"

BBC *Visit the BBC's Reality Check website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

LEFT Colourful lanterns decorate a Beijing park, but the Lunar New Year festivities were cancelled to reduce risk of infection

ABOVE In Zhongnan Hospital, Wuhan, a doctor and a patient bid each other greetings for the Lunar New Year

WHEN DID THE OUTBREAK START?

On 31 December 2019, China contacted the World Health Organization (WHO) to inform them of an outbreak of 'pneumonia of unknown cause' in Wuhan, a city in the country's central Hubei province.

A week later, on 7 January 2020, the Chinese authorities investigating the outbreak confirmed that a previously unknown strain of coronavirus was to blame. It was believed to have originated in one of Wuhan's animal markets, where it had jumped species from an as-yet-unidentified animal into humans.

By 11 January the coronavirus, temporarily designated 2019-nCoV, had claimed its first life. Over the next 10 days, the news broke that human-to-human transmission of 2019-nCoV was possible. The virus killed two more people, and cases of it turned up in Thailand, Japan, South Korea, Vietnam and the US. WHO met to determine whether the situation constituted a global emergency.

As of Monday 27 January, less than a month after the initial alert, 10 cities in Hubei are in a state of lockdown and airports around the globe are screening passengers arriving from Wuhan. The virus has reached Australia and France, the number of confirmed cases is up to almost 3,000 and rising.

BUT HOW SERIOUS IS IT?

The 2019-nCoV virus presents with flu-like symptoms but is capable of causing respiratory distress, pneumonia and potentially death. Furthermore, it's contagious before the symptoms show.

"It's a serious situation. We're approaching it with caution but I don't think alarm," says Prof Mark Fielder, a medical microbiologist at Kingston University. "What we need to remember is that most of the cases – in fact, I'm going to say all of the cases as things stand now – have come from people with direct links to Wuhan or other local cities where the virus is known to be present."

According to Fielder, the virus hasn't moved into people without direct links to Wuhan – it will be more concerning if that happens. Many people, once they are given supportive care, seem to fight the virus off and get better. "A number of the patients who unfortunately lost their lives have also had other diseases, so they've perhaps not been quite so fit in the first place," says Fielder.

At the time of writing, the coronavirus is still spreading. But despite the seemingly steep rise in the number of cases, the outbreak remains within estimates of its expected incidence. WHO has put the total number of expected cases at 4,000, with a margin for error from 1,000 to 9,700.

"[The reason] we've seen a rise in the number of cases is, I think, a conglomeration of factors. If it did emerge from this market, which does seem likely, then obviously quite a lot of people attended that market, especially as people were probably getting provisions for the New Year celebrations in China," explains Fielder. "But we can't tell how many people were in that market and where they went afterwards or where they'd come from before. Also, it takes about five days for the symptoms to appear, so there would have been a delay from exposure to symptom formation. And perhaps we're now seeing relatives of those infected, and people who have been caring for them, succumbing themselves." The length of 2019-nCoV's incubation period explains the sudden jump in the number of confirmed cases. Transmission may be slowing but cases will continue to appear due to the time it takes for the infection to present. Ensuring China has sufficient capacity to deal with the cases that are still to appear is why it's currently rushing to build new hospitals.

WHY IS THERE SUCH A WIDE MARGIN OF ERROR?

The wide margin for error associated with WHO's estimate ►

GETTY IMAGES, SHUTTERSTOCK

suggests a lot of uncertainty. But the mathematical models that produced the estimate are deemed to be reliable – they're the same ones used to anticipate and prepare for the annual outbreaks of influenza. "The margins are so wide because it's so difficult to predict how much a virus will spread in a population, especially a respiratory-based virus," says Fielder. "If the people in Wuhan adhere to the lack of gathering … they're not going out and being in groups where somebody could easily cough, sneeze or do something else that spreads the virus inadvertently. Assuming those parameters are adhered to, contact will be less. If contact is less, then the chances of the virus spreading are decreased.

"But there has to be a reasonable margin of error because people may move around despite the fact they've been told not to. That's the problem with dealing with humans, it's difficult to guarantee that they'll do what they're asked."

That 'human element' is partly why the lockdown in Wuhan and surrounding cities was deemed necessary. By introducing quarantine conditions, the authorities can limit the number of people 2019-nCoV is exposed to, which limits its ability to mutate into something more virulent and/or transmissible.

WILL IT REACH THE UK?

Matt Hancock, the Secretary of State for Health and Social Care, told Parliament in late January that it's increasingly likely 2019-nCoV will turn up in the UK. The good news for anyone showing such symptoms, according to Dr Adam Kucharski, an associate professor in infectious disease at the London School of Hygiene, is that a diagnostic test for 2019-nCoV has already been developed. "One of the things that's been remarkable in this outbreak is the speed at which the information required to develop a test has been made available. Very quickly we were seeing genetic information on this virus being shared and a lot of tools can be developed off the back of that."

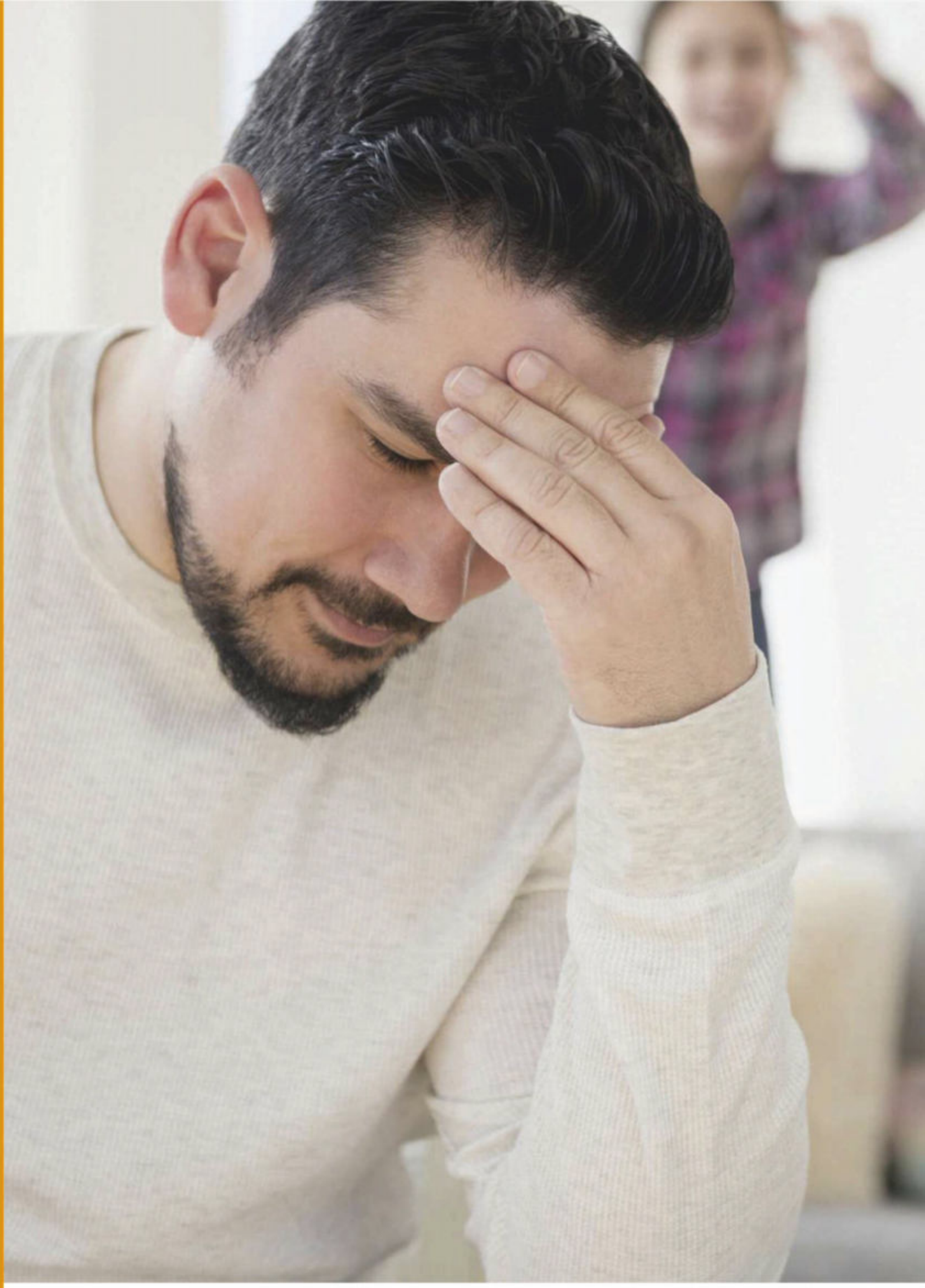
It seems then that as things stand, unless you've had contact with someone who has a respiratory disease who's come from Wuhan or China, your chances of contracting the virus are low and if you do, then doctors will be able to help.

by **ROB BANINO**

Rob is a freelance science and technology writer, based in Bristol.

DISCOVER MORE

WHO advice for protecting yourself and others
bit.ly/WHO_health_tips



ANALYSIS

LATE 40s: IS THIS THE MOST MISERABLE TIME OF OUR LIVES?

A recent study found that happiness reaches a low at 47.2 years old. Does the claim stand up to scrutiny?

What's the unhappiest age? According to a recent study, it's our late 40s. Our happiness, it seems, tends to decrease towards this midlife nadir, before steadily increasing through our 50s and 60s. In the study, Dr David Blanchflower, professor of economics at Dartmouth College in New Hampshire, US, compared 109 data files of happiness statistics from around the world, plotting the relationships between wellbeing and age for hundreds of thousands of people. He found the 'happiness curve' in data from 132 countries, controlling for factors that affect wellbeing, such as education, marital status and employment status. For

“There are plenty of people in their late 40s who are having the time of their life”

developing countries, happiness was lowest at 48.2 years old; in developed countries it was 47.2.

“No ifs, no buts, wellbeing is U-shaped in age,” writes Blanchflower. “I found it in Europe, Asia, North and South America, in Australasia and Africa ... There were very few countries I did not find it for, and that happened mostly where there were small samples or I had no data.”

Previous studies have found this happiness curve, too. Some of the best evidence comes from longitudinal studies, which track the same group of people over a number of years. For example, a 2015 study led by health economist Dr Terence Cheng, looked at individual changes in wellbeing in longitudinal data from Britain, Australia and Germany, finding “powerful support for a U-shape”.

However, some experts question whether the curve is a true phenomenon, or a result of the data analysis. One possibility, says Dr Dean Burnett – author of *The Happy Brain* and honorary research associate at Cardiff University’s School of Psychology – is that the curve at least partly results from unhappier people dying younger, which would skew the data towards higher happiness for the older ages. That said, there *are* reasons why happiness might follow this trajectory when averaged over a population.

GETTY IMAGES

ABOVE People in their late 40s have a lot on their plate, like mortgages to pay and children to bring up. Plus, niggling aches and pains may set in

“Around the late 40s and early 50s is a time when many people have less autonomy and less financial security,” he says. “When you’re younger, you’re not tied down with responsibilities, and there are more possibilities. In midlife, people might have mortgages to pay and adolescent children to look after. Your body might be starting to get aches and pains, and there’s less novelty in life. All of the things you were looking forward to when you were younger have either happened, or are looking less likely to happen.”

So why might happiness increase in later life?

“When you’re older, autonomy usually increases,” says Burnett. “Your children are grown up, you have less responsibility, you might be retired – you have more control over your life again. You’ve also had some time to make peace with any challenges that you began to encounter in your 40s and 50s.”

Another benefit of being older, says Burnett, is that you’ve built up life experience, and that can help you to deal better with any negative life events. “You also become more grateful for the things that you *do* have,” he adds. “You come to terms with the things you aren’t going to get, and can concentrate on other things, such as friendships or hobbies.”

The studies that have found the happiness curve include some broad definitions of happiness. In the Blanchflower analysis, for example, the UK data came from the Annual Population Survey, which asks participants to rate, on a scale of 0 to 10: “Overall, how satisfied are you with your life nowadays?” and “How happy did you feel yesterday?”.

Individual differences will vary greatly from the statistical average, and everyone will have their own personal happiness trajectory. So to what extent can we affect our own happiness? “We have a lot more control than we realise,” says Burnett. “We have the autonomy to do things and make decisions that’ll improve our wellbeing. But we also don’t realise how much of our happiness is influenced by others.” He says that a lot of the things that we think will make us happy – like marriage or a particular job – come from our culture, not from any real need.

Burnett recommends being aware of this when setting goals for the future. “How many of these are things that you *actually* want, and how many are things that you feel you *should* want?” he says.

Ultimately, it seems that people can be unhappy at any age. But they can be happy at any age, too. “There are plenty of people in their late 40s who are having the time of their life,” says Burnett.

by **JAMES LLOYD**

James is staff writer at BBC Science Focus.

COMMENT

AUSTRALIAN WILDFIRES: IS THERE ANYTHING THAT CAN BE DONE TO STOP THE WORLD BURNING?

Australia has been on fire since September. Habitats have been destroyed and homes have been burnt to the ground. But there are ways we can reduce the impact of wildfire, says disaster expert Prof Bill McGuire

On our overheating planet, wildfire is now one of the most terrifying and costly of all natural disasters. From California to Russia, Australia to the UK and Greenland to the Amazon, record temperatures and tinder box conditions have, in recent years, driven conflagrations that have taken hundreds of lives and immolated many thousands of properties – in some cases entire communities.

BURNING ISSUE

Two years ago, major burns in California resulted in the deadliest and most destructive wildfire season ever recorded, with more than 80 deaths and 750,000 hectares scorched at a cost of $12bn (£9bn). In 2019, it was the Brazilian Amazon that burned, helped by fires started deliberately by farmers and loggers. This year, it is Australia's turn, with the most widespread bushfires on record continuing to spread devastation.

As of mid-January, a staggering and unprecedented 8,500,000 hectares of bush and forest in Australia has been turned to ash – an area equal to the size of Austria – and the cost is set to rise above AU$5bn (£2.6bn), with months of the fire season still to go. There are other costs too. While the country's bush and eucalyptus forest is particularly resilient to fire and will soon recover, its fauna is not. The blazes may already have taken the lives of more than one billion animals, which could have a long-term impact on populations of at-risk koalas and other vulnerable species.

> “For thousands of years, nomadic aboriginals played a key role in preventing conflagrations by burning surface vegetation to create firebreaks”

Looking at images and film of the Australian fires, it is easy to believe that they are unstoppable; that nothing can be done to limit their scale and the destruction they bring, but this is not the case. While battling great conflagrations once they are in full spate is almost a lost cause, measures can be taken in advance to try and manage the occurrence of fires and to limit their potential to grow into colossal blazes that are nearly impossible to control. And such measures are nothing new. In fact, Australia's indigenous population has a long history of successfully managing fire. For thousands of years, nomadic aboriginals played a key role in preventing conflagrations by burning surface vegetation to create firebreaks that constrained the scale of fires started naturally by lightning. The fires were set during the cooler months, so as to limit their reach, leaving behind stretches of land cleared of the dry plant debris that fuels much larger conflagrations. As the aboriginal populations dwindled and their lifestyle was destroyed, so too was this invaluable service.

Now, however, using traditional practices to start so-called controlled or hazard reduction burns are being taken seriously by stakeholders in the fire management business. There have already been some small-scale successes in managing bushfire activity, most notably where traditional methods have been combined with modern technologies like satellite mapping and controlled aerial ignition using helicopters or drones. And the ideas are catching on elsewhere too. In Venezuela, indigenous knowledge and modern techniques are

ALAMY

In Arnhem Land, Northern Territory, an aboriginal elder teaches children how to make a controlled fire to burn off dangerous grasses ahead of fire season

being used together to manage fires in the country's Canaima National Park, while methods and strategies implemented in Australia are being exported to places as far afield as Botswana, Brazil and Canada.

DESERT COUNTRY

There are other things that can be done too, in order to clamp down on wildfires and their impacts. More sophisticated computer models are able to predict how a blaze will develop, allowing better planning of fire-fighting resources. As towns sprawl into wildland areas where fires are more common, the interface between the two becomes a critical zone, where preventative strategies can help keep buildings safe. These include maintaining a wide vegetation-free zone around properties, using fire-resistant building materials and keeping gutters and decking free of burnable debris. Injury and loss of life can be minimised by planning multiple evacuation routes in advance, and by ensuring that there is always access for fire-fighting vehicles.

Even taken together, however, such mitigation methods amount to little more than a sticking plaster. Looking ahead, prospects in countries prone to burning look bleak. Even armed with new models and methodologies, in the continuing war against wildfires, it is likely that stakeholders will be battling just to stay still. As global heating accelerates, unprecedented temperatures, extreme drought conditions and failing water supplies will conspire to bring ever more devastating conflagrations.

In Australia, 2019 was the hottest year on record and the driest for nearly 120 years. December saw more than three-quarters of the country experiencing the worst fire weather conditions on record. As the fires continue to rampage through fully grown forest as well as bush, it is worth noting that Australia is essentially a desert with a few green bits around the edge. It's hardly surprising that as Hothouse Earth conditions start to become the norm, these bits become crisped and burned by heat and fire, leading to questions being asked about the country's long-term future on an overheated world. Whisper it, but maybe – at long last – the recognition that the fate of Australia is at stake will cause climate change deniers involved in the country's decision-making to rethink their views on emissions. **SF**

—

by **PROF BILL MCGUIRE**

Bill is professor emeritus of geophysical & climate hazards at UCL, a co-director of the New Weather Institute and a patron of Scientists for Global Responsibility. His environmental thriller, Skyseed, *will be published later this year.*

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↗ The new Segway S-Pod: a sofa on wheels? p42

INNOVATIONS

CES 2020 SPECIAL REPORT

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Watch an episode of *Click* from CES in Las Vegas.
bit.ly/click_vegas

SLEEP TECH

Motion Pillow

For those who snore, this smart pillow is able to raise, turn and lower your head during the night when it detects that discordant drone.

Hatch Restore sleep light

This is one of the best sleep lights we've seen. Set a routine that suits, and the Restore will help you meditate, wind down, sleep soundly and wake on time.

Climate360 Smart Bed

Winner of the CES 2020 Best of Innovation: Smart Home award, this bed creates a personalised sleeping climate. It even warms your feet to aid sleep.

FIRST LOOK

All the highlights from the world's biggest tech show

Tech enthusiasts descended upon Las Vegas for the 2020 Consumer Electronics Show (CES)

Since its inception in 1967, CES has provided a glimpse into the future. In 2001, Bill Gates unveiled Microsoft's new gaming console: the Xbox. In 2003, Blu-ray DVDs were the next big thing – though that didn't really pan out. And in 2013, the Oculus Rift was first revealed to journalists in a small corner of the show's sprawling halls.

This time around the show was dominated by TVs, perhaps with tech companies casting an eye towards the upcoming Tokyo Olympics which will be the first to be broadcast in 8K. A large screen is necessary to really enjoy this resolution, so Samsung made sure it would win the inevitable size contest with its 292-inch display called The Wall. Made from microLEDs, it's designed to use minimal energy and never be turned off, switching to a 'digital canvas' to match the owner's interior needs.

Monstrously big TVs weren't the only screen tech taking over the show. Foldable-display phones from Dell, Huawei and Samsung pulled in crowds, while Lenovo announced that 2020 is the year its foldable-display laptop, ThinkPad X1 Fold, will be available to buy, with prices starting at $2,499 (£2,000 approx).

CES is a place of concepts and prototypes. One such announcement was the Alienware Concept UFO from Dell. Familiar in design and feel to the Nintendo Switch, the Concept UFO will have detachable controllers on either side of its screen. The main draw is the flexibility of the device: it's a handheld Windows 10 PC and runs any game from your PC library or Steam account.

Less 'electronic' and more 'consumer' was the presence of Impossible Foods, the company responsible for the plant-based Impossible Burger. They launched Impossible Pork to crowds this year and it went down a treat. Testers vouched for the soy-based meat-replacement, claiming it looked, smelled and even tasted just like the real thing.

Of all the trends playing out on the show floor, one thing is clear: our homes are getting smarter, with digital personal assistants, robot butlers and smart fridges all vying for a place in your home. Whether we want them there or not though, is yet to be decided.

> "MONSTROUSLY BIG TELEVISIONS WEREN'T THE ONLY SCREEN TECH TAKING OVER THE SHOW IN LAS VEGAS"

Lenovo's ThinkPad X1 Fold is the world's first foldable-display PC, and will be available to buy later this year

CES for audiophiles

From huge strip speakers to tiny wireless earbuds, CES is the audio-lover's paradise. Here's our pick of the best on show this year

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1. Audio, video and voice assistant

Made by flexible screen specialists Royole, the Mirage smart speaker could replace several of your home gadgets. It's powered by Amazon Alexa voice service, though it's considerably bigger than an Amazon Echo speaker in order to accommodate an eight-inch AMOLED screen, wrapped seamlessly around the unit. You can make and receive video calls using the five megapixel camera, or use the screen to present visuals. Royole's partnership with audio brand Cleer gives the Mirage an impressive, 360° sound quality.

Royole Mirage smart speaker, £799, royole.com

2. For shower karaoke

There are lots of shower speakers out there, but some compromise on sound. The new Kohler Moxie showerhead has built-in audio from Harman Kardon, so there's no concessions here. It's completely waterproof – it has to be, since it sits in the centre of the showerhead using a magnetic docking system, meaning it doubles as a portable speaker too – and has been tuned to cancel out the noise of the water. If you want to request songs on demand, you can connect any Bluetooth device or even upgrade to the Alexa enabled version.

Kohler Moxie showerhead, From £130, kohler.co.uk

3. A personalised listening experience

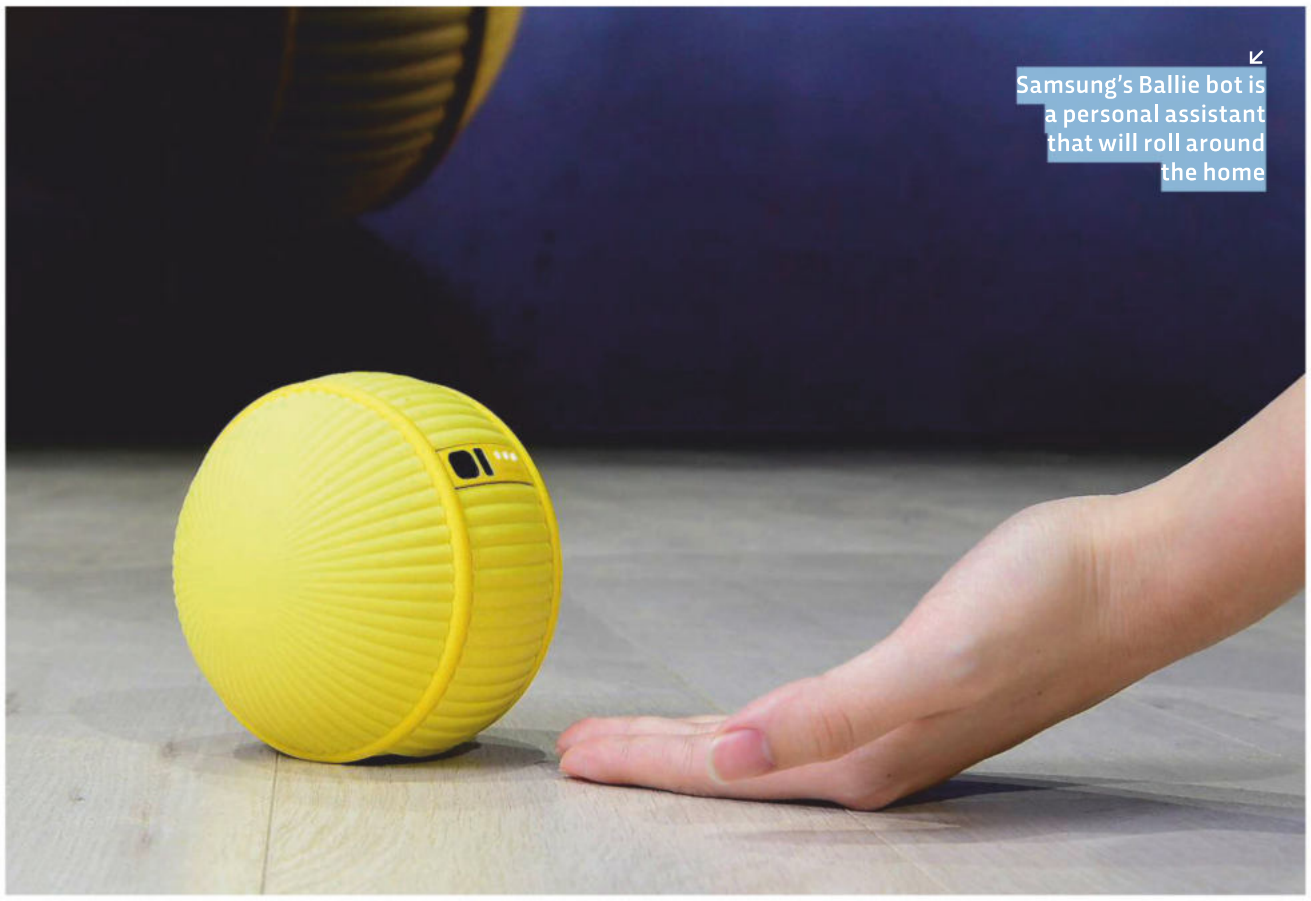
CES was awash with wireless earbuds, at a range of different prices. When we heard Audio-Technica was launching a new product, we had to check them out. The noise-cancelling ATH-ANC300TW earbuds are the brand's most advanced set. One of our favourite features is the hear-through function, which lets external sound in when you tap the earbud – useful for conversations or airport announcements. The app provides three presets to control the strength of the noise-cancelling effect.

Audio-Technica ATH-ANC300TW, £209, eu.audio-technica.com

4. Inspired by DJs

Noise-cancelling headphones are great for cutting out consistent, low frequency sounds like an aeroplane engine during a flight. But the more complicated the noise you're trying to eliminate, the harder the task gets for the headphones. That's why JBL's new headphones, which claim to be ideal for DJs trying to drown out the cacophony of a nightclub, caught our attention. If they can do this effectively then they'll be some of the most advanced headphones out there. They even feature drivers made out of graphene (remember that material?).

JBL Club headphones, from $149 (approx £115), out in spring, uk.jbl.com



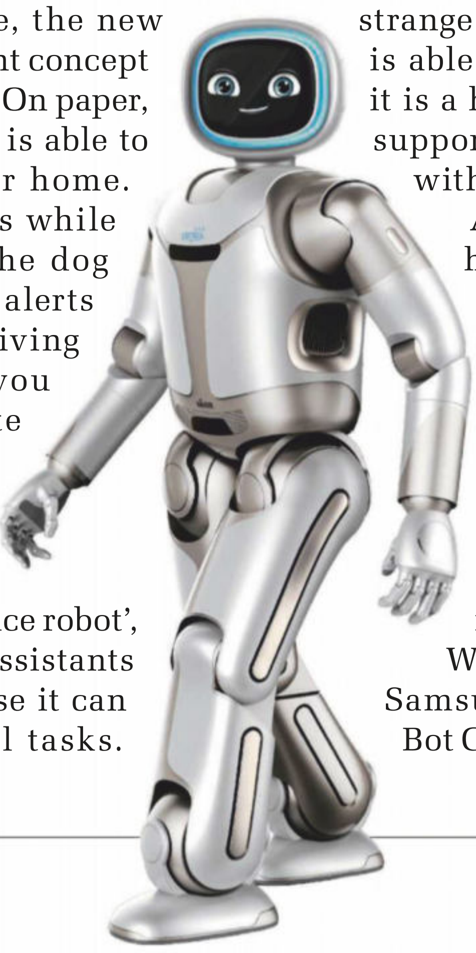
Samsung's Ballie bot is a personal assistant that will roll around the home

Bring on the robot butlers

Robots promise to provide a helping hand around the house as AI personal assistants make strides

For a long time, innovations have focused on making us more connected with each other. Now, we are becoming more connected to our things. Household items are no longer just 'smart' – they are adaptive, mobile and some even have what you might call a personality.

Take Samsung's Ballie, the new ball-like personal assistant concept that was launched at CES. On paper, it's a voice-assistant that is able to follow you around your home. It keeps an eye on things while you're away, watches the dog make a mess and gently alerts you to 'clean up in the living room', and reminds you to water your favourite pot plant.

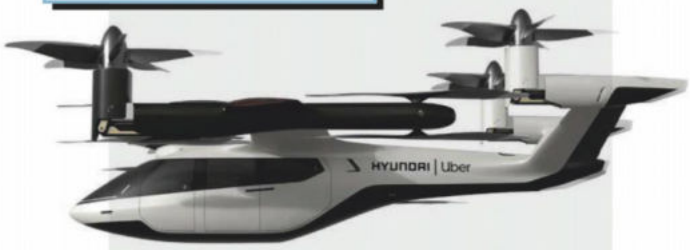


Taking a more human form is UBTECH's Walker home butler. Dubbed a 'humanoid service robot', Walker surpasses home assistants like Ballie simply because it can actually perform useful tasks. Walker is able to pick up and hand over a basket of shopping from a trolley, open a bottle of cola and pour it into a glass, and even perform a yoga routine. It's a strange thing to behold. As Walker is able to go up and down stairs, it is a huge deal when it comes to supporting the elderly and those with disabilities.

"HOUSEHOLD ITEMS ARE NO LONGER JUST SMART – THEY ARE MOBILE AND HAVE PERSONALITIES"

Accessibility is where these home robots will truly shine. In fact, Samsung designed their Bot Chef with exactly this in mind. Two robotic arms on the kitchen counter make up this smart sous chef, referred to as a 'co-bot' – a collaborative robot designed to assist, rather than taking over. While currently just a concept, Samsung is aiming to make the Bot Chef affordable. Bon appetit.

BRIEFING



HYUNDAI AND UBER'S S-A1 AIR TAXI

Is it a bird? Is it a plane?
No, it's a Personal Air Vehicle. Developed by Hyundai, the S-A1 is designed to take off from vertical, then switch to horizontal during flight, before landing vertically. The concept unveiled at CES could carry four passengers plus a pilot, with a cruising speed of up to 290km/h at altitudes of 300 to 600 metres.

Is it safe?
Hyundai has included 'redundant' rotors, to "make sure that a motor failure won't crash the taxi". There is also a parachute, in case of emergencies. The S-A1 will be piloted initially, with the intention of becoming autonomous in the future. It's powered by electricity and will apparently only require up to seven minutes to recharge.

Can I get one home from the pub?
Not tonight, we're afraid. Uber hopes to perform test flights this year and is planning to launch a shared air taxi service in 2023. Initially, this will only be in Dallas, Los Angeles and Melbourne, but considering how far and how rapidly the ride-sharing platform has spread on the ground, one can only imagine what the next decade

The good, the bad and the downright weird...

For every life-changing piece of tech at CES, there's always a gadget around the corner that will leave you scratching your head. Here's our pick of the tech we're still thinking about a month later...

←

Samsung Shoe Care System

This year, Samsung unveiled a huge number of new products and concepts, but the Shoe Care System seems to be taking things a step too far. Pegged exclusively for your smelly trainers, it will dry, deodorise and sanitise your footwear. It will take up a chunk of space – it's perhaps three-quarters of the size of a small fridge – and based on its cousin the AirDresser's price, is bound to cost upwards of £2,000...

£TBC, samsung.com

SEGWAY
SEGWAY

→

Segway S-Pod

This isn't a prop from a *WALL-E* reboot, but an egg-shaped two-wheeler that could soon be transporting you around airports or shopping centres. The Segway S-Pod is said to be much easier to manoeuvre than previous iterations, although some have called it a 'ridiculous lounge chair on wheels'.

£TBC, segway.com

Numi 2.0

You can't ignore the call of nature, even in the middle of the night. Instead of navigating the bathroom in the dark, the Numi 2.0 will greet you with a nightlight, quietly opening its lid and gently warming the seat for you. Stand up, walk away, and Numi 2.0 will flush and close the lid. For those who like to ponder on the potty, Amazon's Alexa is built-in.

£TBC, kohler.co.uk

↓

Petit Qoobo

A headless cat pillow with wagging tail sounds downright useless – until you try it. Designed to comfort those who can't have a pet of their own, the Petit Qoobo responds to sounds or being touched: call its name and it's happy to see you. The underbelly vibrates, mimicking a heartbeat, and it's oddly comforting. It's less effort and less expensive than a real cat, but it may get some funny looks from your houseguests.

$149 (£115 approx), qooboo.info

Charmin
#ENJOYTHEGO
Charmin

Charmin Rollbot

Never again feel the dread from finding an empty toilet paper tube, as the Rollbot brings you a fresh Charmin roll when you need it most. It may seem amusing, but it could be useful for people with disabilities and those who live alone.

So is this a serious smart home solution? "The problem is serious, but this is a prototype," the inventors explained. There are no plans for it to go on sale. Shame.

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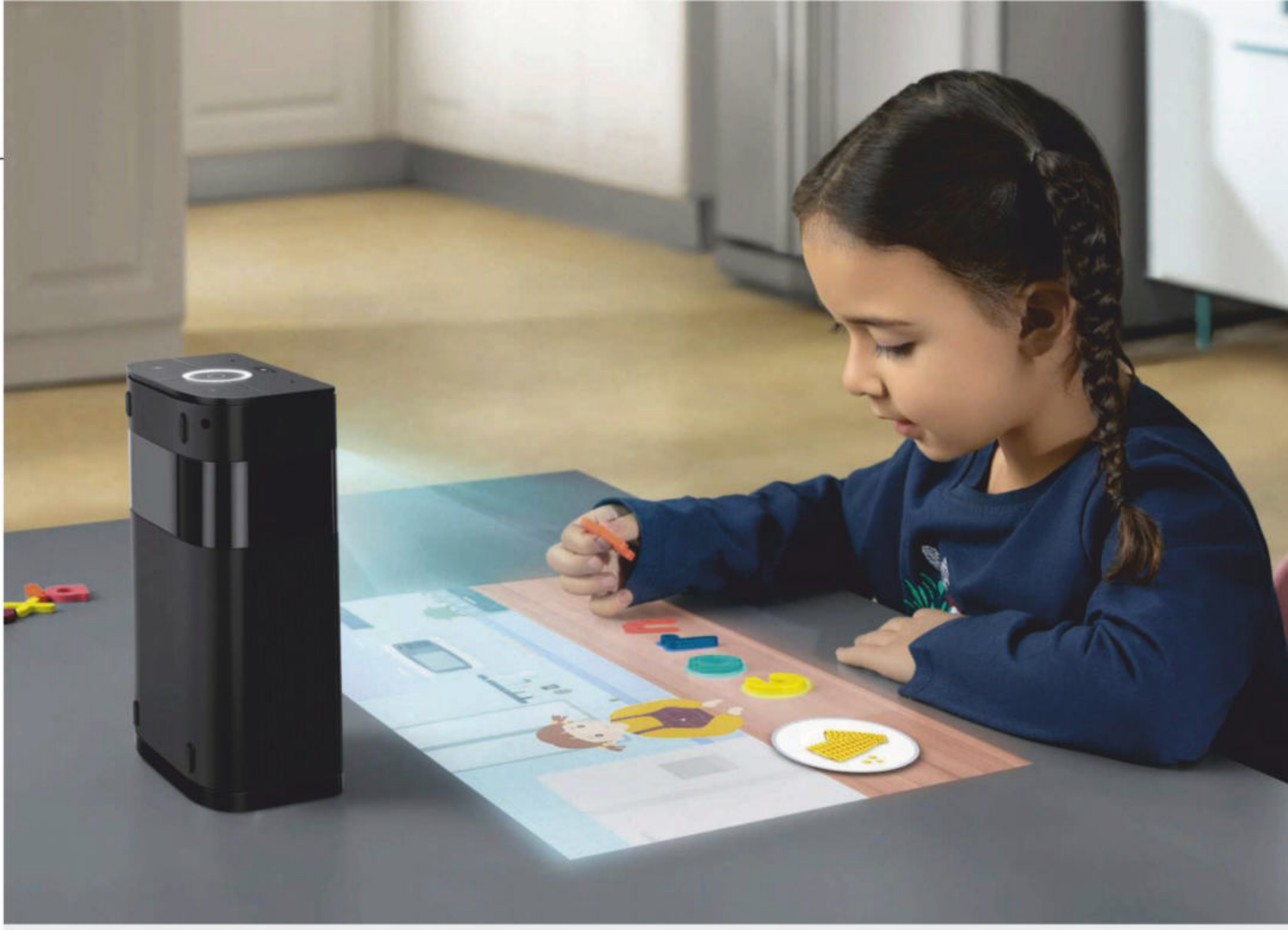
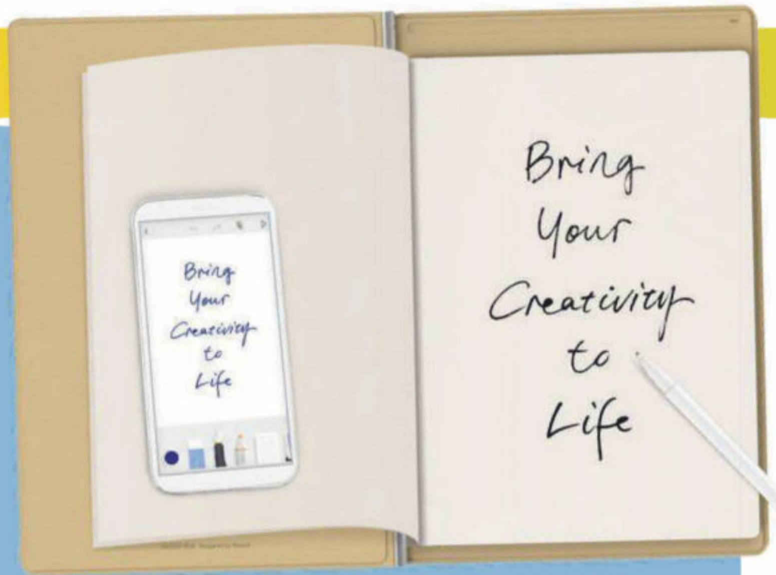


Hachi Infinite

A CES Innovation Award honoree, the Hachi Infinite artificial intelligence terminal is essentially a portable smart projector. It can turn any flat surface into a touch screen. With the built-in Android operating system, your breakfast table can become a tablet, or your office desk a piano. Artificial intelligence allows it to recognise food placed in front of it, making it an interactive recipe book. With voice control from Amazon Alexa and an HD camera, the Hachi Infinite could quickly replace all other smart assistants in your home.

£TBC, hachismart.com



Royole RoWrite 2

Royole are known for their flexible screens – they were the first to bring a foldable smartphone to the commercial market. Here, they put that technology to use, in RoWrite 2's leather binding. Imagine it as an expensive, yet impressive, Moleskine notebook. You don't need a special pen or paper, just scribble down your notes and watch them appear in the cloud, which can then be accessed on any smart device.

£129, royole.com

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OUT OF THIS WORLD

EARTH'S MOST EXTREME ENVIRONMENTS NOW HOST TEAMS OF ASTRONAUTS WHO ARE EXPERIMENTING WITH THE TOOLS, SKILLS AND PROTOCOLS THEY'LL NEED TO LIVE ON ANOTHER PLANET

WORDS: ROB BANINO

←↓

LIFE ON MARS

HI-SEAS, BIG ISLAND, HAWAII, USA

A spacesuit isn't the first outfit that springs to mind for anyone visiting Hawaii. That's unless you're spending eight months in the HI-SEAS (Hawaii Space Exploration Analog and Simulation) habitat on Mauna Loa volcano.

HI-SEAS allows researchers to study how people cope with the confinement, isolation and psychological pressures of long-duration space missions, such as one to Mars. To add to the realism, there's a 20-minute communications delay with mission control, and anyone who steps out into Mauna Loa's Mars-like environment – such as Dr Martha Lenio (seen collecting rock samples on the previous page) – has to suit up.

Realism has given way to practicality on occasion, though, such as when budget constraints meant that hazmat suits replaced spacesuits, and shipping containers served as 'robotic resupply ships' (below). Even so, lessons learnt during these missions, which can last for up to a year, are no less valid for aspiring astronauts. "It taught me the importance of having a sense of humour, strong communication skills and a flexible personality," says Lenio.

→

IN DEEP WATER

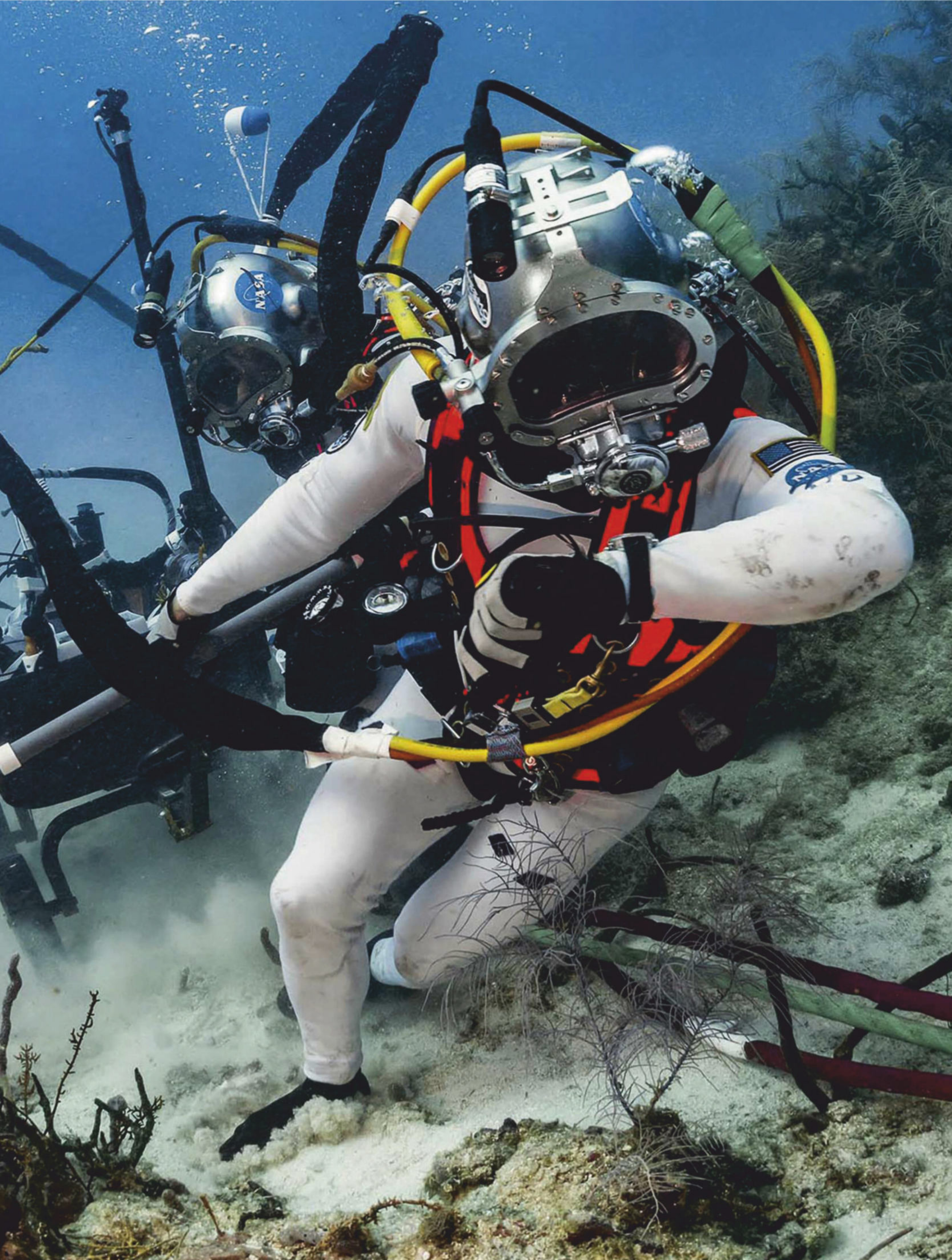
NEEMO, KEY LARGO, FLORIDA, USA

Reproducing the reduced-gravity environment and time pressure of walking on the Moon or another planet can be a struggle. Unless that is, you go underwater, like the 'aquanauts' of the NEEMO (NASA Extreme Environment Mission Operations) programme. Each NEEMO mission sees up to six prospective astronauts descend 19 metres to the Aquarius base – a cramped 37m^2 habitat on the seabed 5.6 kilometres (3.5 miles) off the coast of Florida – to experience living and working in an alien space.

Pictured here is the NEEMO 22 mission, which took place during June 2017. The team is testing out the Modular Equipment Transporter System (METS), a four-wheeled cart containing interchangeable pods of tools and instruments to help astronauts carry kit over rugged terrain. Every second counts when you're exploring another planet. As such, the more equipment you can bring to a sampling site, the more you can maximise your time there.

As well as putting METS through its paces, the 10-day expedition also conducted in situ analysis of coral and tested out evacuation procedures.

HI-SEAS/UNIVERISTY OF HAWAII, NASA ANALOGS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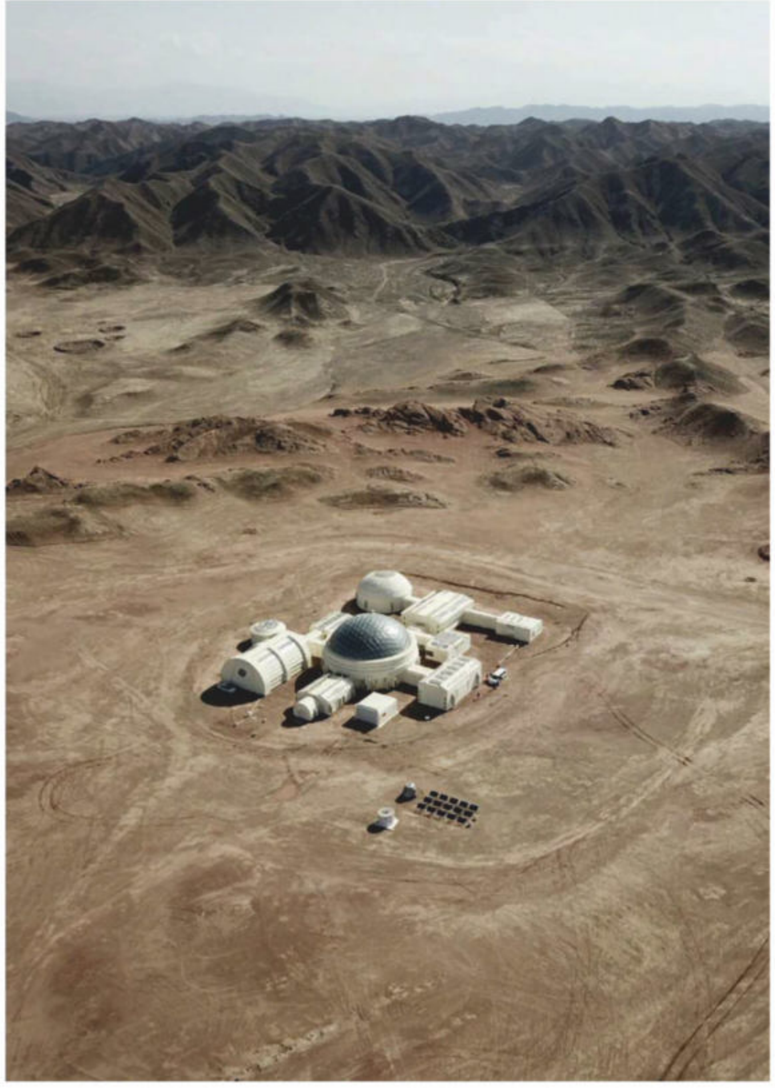

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MARTIAN GETAWAY

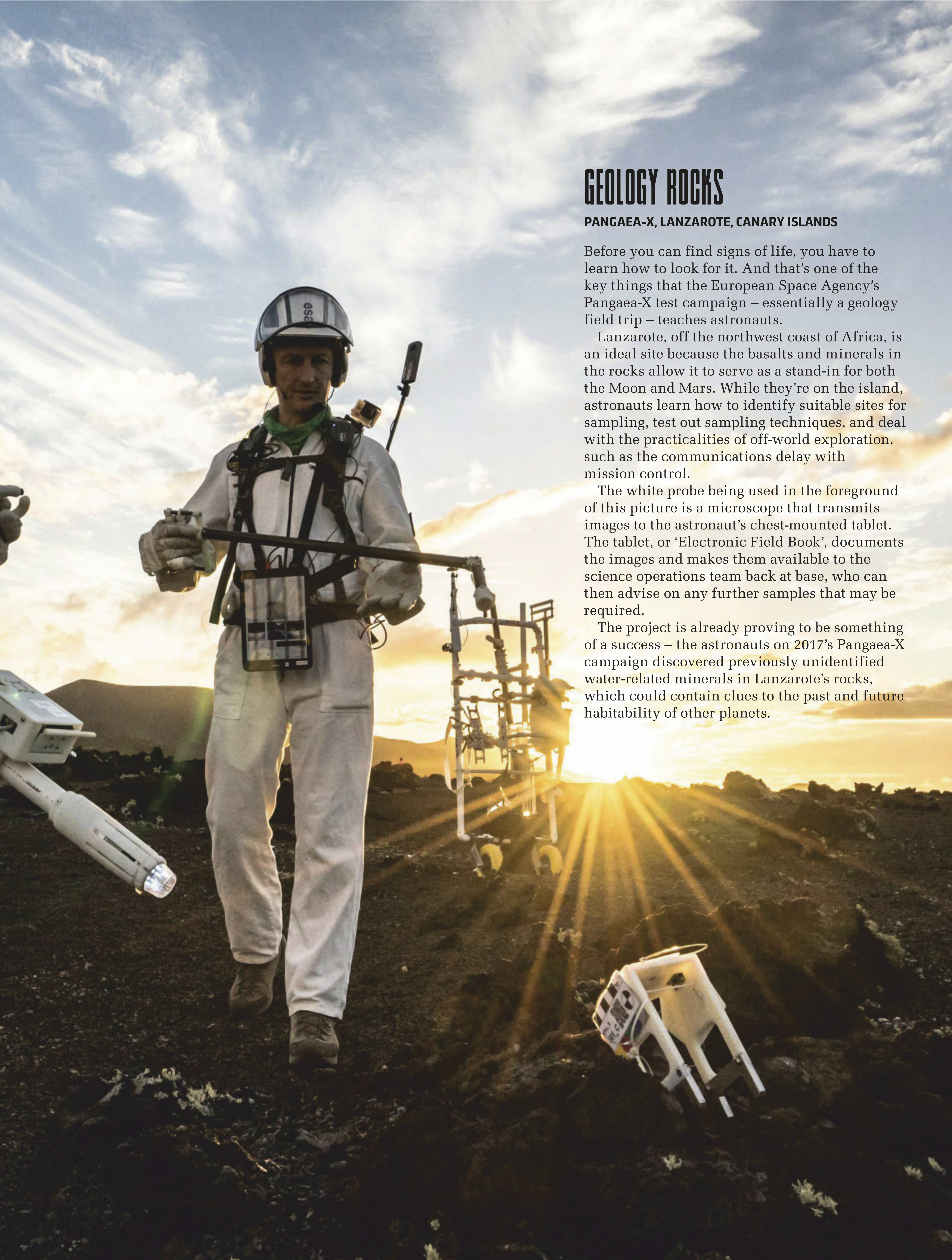
C-SPACE PROJECT, GOBI DESERT, CHINA

If China's long-term plans to send a crewed mission to Mars go ahead, some of its taikonauts' training is likely to take place here, at the C-Space Project's simulated Martian base. For now, though, it's tourists and schoolkids who have the run of the place.

The facility opened in April 2019, and is located in the Gobi Desert about 40 kilometres (25 miles) outside the city of Jinchang in the Gansu province. Made up of nine linked modules – including living quarters, a control room and a mock airlock – it's designed to give visitors an idea of what it's like to work in an environment where resources are limited and every aspect of life must be monitored and controlled.

The project was dreamt up by Gansu officials and the Jinchang Star Universe Culture and Tourism Investment Company, in a bid to boost tourism in one of China's poorer regions. But it's been developed in collaboration with the Astronaut Center of China, and with further investment and expansion, is intended to become an official taikonaut training site.

GETTY IMAGES, ESA/A ROMEO



GEOLOGY ROCKS

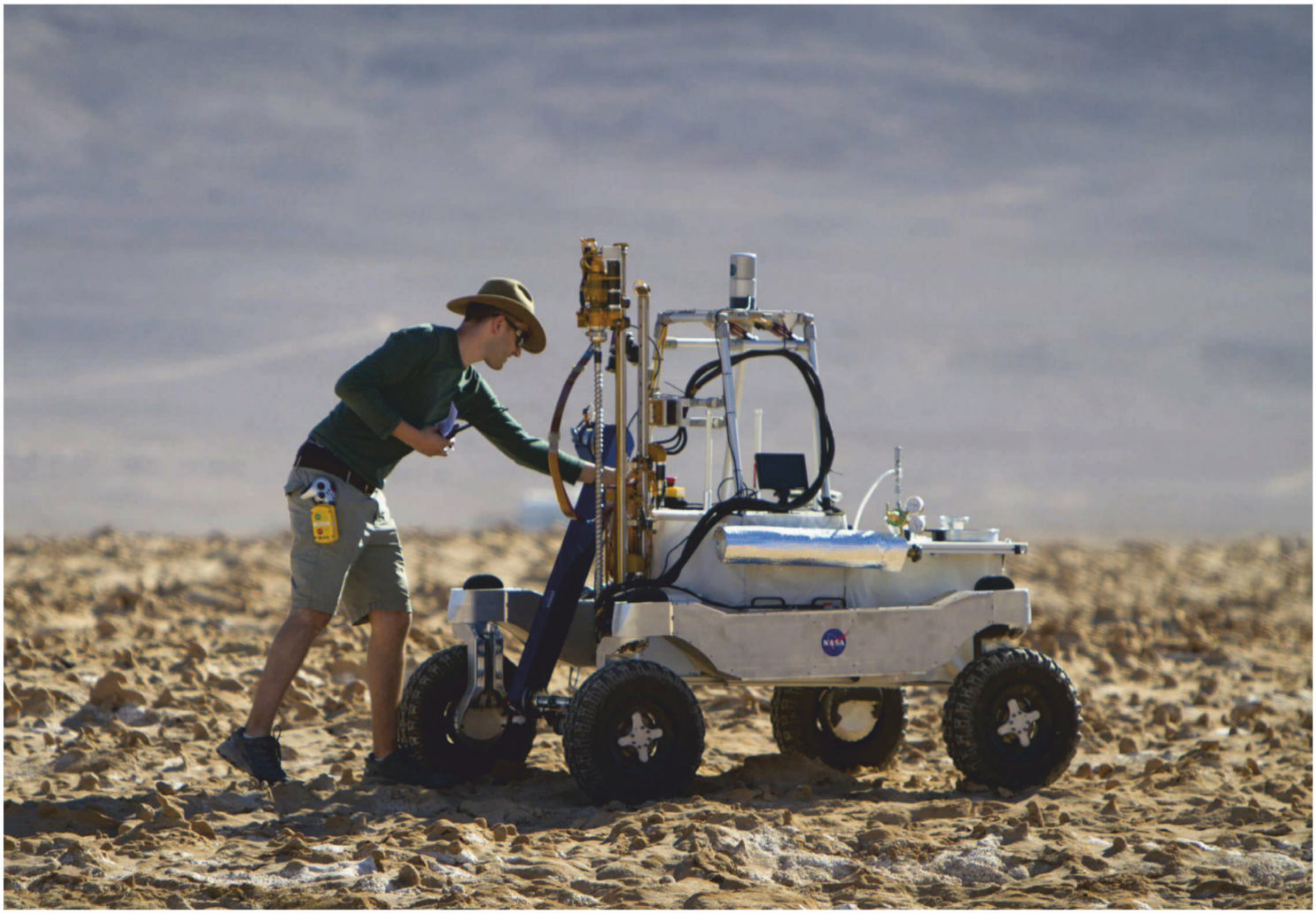
PANGAEA-X, LANZAROTE, CANARY ISLANDS

Before you can find signs of life, you have to learn how to look for it. And that's one of the key things that the European Space Agency's Pangaea-X test campaign – essentially a geology field trip – teaches astronauts.

Lanzarote, off the northwest coast of Africa, is an ideal site because the basalts and minerals in the rocks allow it to serve as a stand-in for both the Moon and Mars. While they're on the island, astronauts learn how to identify suitable sites for sampling, test out sampling techniques, and deal with the practicalities of off-world exploration, such as the communications delay with mission control.

The white probe being used in the foreground of this picture is a microscope that transmits images to the astronaut's chest-mounted tablet. The tablet, or 'Electronic Field Book', documents the images and makes them available to the science operations team back at base, who can then advise on any further samples that may be required.

The project is already proving to be something of a success – the astronauts on 2017's Pangaea-X campaign discovered previously unidentified water-related minerals in Lanzarote's rocks, which could contain clues to the past and future habitability of other planets.



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HIGH AND DRY

ARADS, ATACAMA DESERT, CHILE

The Atacama Desert reaches an altitude of up to 4,000 metres. It gets less than 15 millimetres of rainfall a year, on average, and is persistently exposed to strong ultraviolet rays from the Sun. It's one of the harshest, driest places on Earth, but it's not devoid of life. There are microbes hidden in rocks and buried underground, just as there could be on Mars, which is why NASA comes here to test ways of searching for them.

Between 2016 and 2019, the Atacama Rover Astrobiology Drilling Studies (ARADS) project came here to test the K-REX2 rover (above). Unlike existing Martian rovers, which can only collect samples from the surface or just below it, this prototype is more advanced. It's equipped with a reactive 'smart' drill, adjusting the pressure needed to bore through different types of geology and collect samples from depths of up to two metres.

→

GOING UNDERGROUND

CAVES PROJECT, SARDINIA, ITALY

Stress affects performance. And with so much at stake – your mission, your spacecraft, the lives of you and your crew – space is probably the most stressful environment there is. As such, any prospective astronaut needs to be able to perform under pressure. Which is where the European Space Agency's CAVES project comes in.

CAVES is an annual two-week course in which astronauts from all over the world learn how to work together by venturing deep into the caves beneath Slovenia or the island of Sardinia, staying underground for six consecutive days.

Living and working in such a confined environment tests everyone's patience to the limit, as they learn to navigate, use tools and maintain the continuous vigilance needed to keep each other safe – the same skills required during a spacewalk. **SF**

by **ROB BANINO**
(@robertbanino)
Rob is a freelance science journalist based in Bristol.

NASA/ARADS, ESA

ILLUSTRATION: VICTOR SOMA

THE MYSTERY OF YOU

To discover what makes us self-aware, researchers from around the world are going head-to-head in a grand competition to determine where consciousness really comes from... by DR CHRISTIAN JARRETT

Scientific advances have sent people to the Moon and to the greatest depths of the ocean. We've split the atom and created computers that can defeat a chess grandmaster. And yet science still can't explain arguably the most fundamental aspect of existence – our subjective experience of existence. Our consciousness.

That's not for a lack of trying. There are many consciousness theories, it's just that none is widely accepted. Part of the reason is the two-tiered nature of the challenge. There's what the Australian philosopher David Chalmers called the 'easy problem' of consciousness, which is explaining the biological processes that underlie mental functions, like perception, memory and attention. But there's also the 'hard problem', which is explaining how and why there is a subjective, first-person aspect to these mental functions (why, when you stub your toe, you don't simply register the damaging contact – it actually hurts). Scientific theories of consciousness particularly struggle with the hard problem – in fact, there's disagreement about whether there really is a hard problem at all.

> “THE AIM IS TO STIMULATE GREATER PROGRESS IN THE CONSCIOUSNESS FIELD, BY REDUCING THE NUMBER OF COMPETING THEORIES”

PROGRESS NEEDED

The Templeton World Charity Foundation (TWCF) – one of a trio of charitable entities established by the US-born British philanthropist John Templeton – believes it can help. The TWCF funds research to 'enrich individual lives and redefine the frontier of human knowledge and progress'. At the end of 2019, it launched a new multimillion dollar funding initiative called Accelerating Research On Consciousness. The aim is to stimulate greater progress in the consciousness field, effectively by reducing the number of competing theories. “I would consider the initiative successful if we kill off one theory,” says Dr Dawid Potgieter at the TWCF, who set up and is overseeing the exercise.

The initiative is based on an approach known as 'adversarial collaboration', where two or more scientists with opposing views work together to resolve issues in science. It is advocated by the Nobel-winning psychologist Daniel Kahneman, who pioneered our understanding of how people make decisions. Indeed, the launch of the new consciousness initiative marked the anniversary of another scientific competition that took place 100 years ago. Arthur Eddington used the total solar eclipse of 1919 to compare the predictions of Einstein's then new General Relativity with Newton's theories. Einstein won. But consciousness is trickier to test ➜

ABOVE Dr Dawid Potgieter from the Templeton World Charity Foundation set up the exercise and is overseeing it

▶ than gravity, so to take part in TWCF's competition, the leaders of two rival consciousness theories have to agree to an experiment that will put their ideas to the test. Each side has to agree that if certain results are obtained, their theory will be disproved. Five such experiments are planned in total, with the first having begun in October 2019.

Potgieter was inspired to launch the new initiative after attending an event organised by the Center For Open Science in 2017, after which he got chatting to people in the field of consciousness research. "Everybody in consciousness said nearly the same thing 'my theory is really great and underappreciated; it's testable and I would love the chance to prove my theory is right and the others are wrong' … a lot of these people didn't even speak to each other within the neuroscience domain, they're quite siloed," he says.

MEETING OF MINDS

The first of the five experiments came out of a two-day meeting organised by Christof Koch, a pioneer in consciousness research, and the president and chief scientist of the Allen Institute for Brain Science in Seattle. Potgieter had invited him to arrange the meeting and choose the attendees, including the leaders of the consciousness theories of his choice, as well as top experimentalists in relevant methodologies, philosophers (to maintain 'conceptual hygiene'), and upcoming young researchers with technical skill and energy, who don't yet have so much stake in the game that they're likely to be biased.

The rules of the meetings are that each is hosted by someone impartial or at least respected. The host picks the other guests, and there are no generic PowerPoint presentations. "The meeting has one goal, which is to come up with an experiment that can critically test one or more theories," says Potgieter. "The mark of success is, at the end, we have an experiment where one or more theorists says, 'yes this result from this experiment will kill off my theory'."

The first meeting led to an agreed experiment that will pitch the Integrated Information Theory of consciousness (IIT) against the Global Neuronal Workspace Theory (GNWT). The former starts by defining what constitutes a conscious experience, and argues for the minimum cognitive machinery necessary to produce it. Meanwhile, the latter suggests consciousness emerges when information is held at a kind of mental junction before it's broadcast out to other parts of the brain. "A key difference ▶

"THE MARK OF SUCCESS IS, AT THE END, WE HAVE AN EXPERIMENT WHERE ONE OR MORE THEORISTS SAYS, 'YES THIS RESULT FROM THIS EXPERIMENT WILL KILL OFF MY THEORY'"

GETTY IMAGES X2

RIVAL CONSCIOUSNESS THEORIES

INTEGRATED INFORMATION THEORY

Proposed by neuroscientists Giulio Tononi and Gerald M Edelman, the theory states that the neural processes that give rise to consciousness have two key properties. The first is integration. When you perceive the world, you experience a single, unified whole that can't be separated or broken down into smaller parts. Consider how it's not possible to be consciously aware of two different scenes simultaneously. The second key property is information, which refers to each conscious experience being highly differentiated or informative – you are having this particular experience rather than an almost infinite number of others. Critics say that, by arguing that any system with these two properties gives rise to consciousness, it is advocating for 'panpsychism' – the idea that consciousness is ubiquitous in the Universe.

GLOBAL WORKSPACE THEORY

Why do we become consciously aware of some things but not others? This theory, first proposed by neurobiologist Bernard Baars, likens our thought processes to a theatre, with most activity going on behind the scenes. When information arrives on the 'stage' or global workspace, it suddenly becomes the focus of our attentional spotlight and enters our conscious awareness. French neuroscientist Prof Stanislas Dehaene has since investigated the neural basis of consciousness of Global Workspace Theory, expanding it to the Global Neuronal Workspace Theory. He proposes that if incoming information has enough salience and we pay enough attention to it, then neural activity spreads beyond the brain's early sensory processing areas, broadcasting to the associative areas in our frontal cortex and the parietal lobes – the 'global workspace' that allows sensory information to reach consciousness.

HIGHER ORDER THEORIES

When you look at an apple, your brain forms a neural representation of the fruit. Neuroscientists call this a 'first-order' representation and those scholars who endorse so-called 'higher order' theories of consciousness, such as the US neuroscientist Dr Joseph LeDoux, believe that the first-order representation always occurs at a non-conscious level. For you to become consciously aware of the apple, LeDoux and others propose that there must be some kind of higher order thought about, or processing of, that initial perception (or thought or feeling) for it to reach your subjective consciousness.

PREDICTIVE CODING THEORIES

Most people are unable to tickle themselves because the brain automatically anticipates the expected sensory consequences of its own willed actions and cancels them out. In fact, prediction is fundamental to our experience of the world, allowing us to overcome the sluggishness and poverty of information arriving via our senses. Advocates for predictive coding theories, like Prof Anil Seth at Sussex University, believe this is key to consciousness – that what we consciously perceive is often based on what we expect rather than what is actually there. Moreover, they see these predictive processes as important not only to our subjective perceptual experiences but also our very sense of self and feelings of ownership over our bodies.

ATTENTION SCHEMA THEORY

Consciousness is not some magical, ghost-like property of the brain that needs explaining, according to this theory. Rather, consciousness is simply the brain's way of modelling what it is currently thinking about and paying attention to. Moreover, this is fundamental to how the brain works rather than dependent on higher order cognitive processes. "The information in the brain is not necessarily literally accurate," says Prof Michael Graziano at Princeton University, who developed the theory. "The brain constructs models – bundles of information – to describe and keep track of things in the world. It models objects in the outside world, and it models its own internal states."

ILLUSIONISM

Attachment Schema Theory is related to 'illusionism' proposed by philosopher Dr Keith Frankish (and related consciousness theories put forward by the philosophers Daniel Dennett and Patricia Churchland). "I believe that we do not have phenomenal consciousness," says Frankish, "it's a kind of introspective illusion, which reflects the limited access we have to our own mental processes. I call this view 'illusionism'. The real task is to explain our intuitions about phenomenal consciousness – why we think we possess it."

QUANTUM THEORIES

Quantum mechanics is the branch of physics that seeks to explain the behaviour of subatomic particles. Studies have thrown up astonishing results, such as that particles can be in two states at once and their behaviour seems to change depending on whether they are being measured or not (apparently challenging the idea of an objective reality). In fact, even an intention to measure them seems to change their behaviour. Advocates of quantum theories of consciousness, like British physicist Roger Penrose, believe this implies consciousness is somehow linked with the quantum world, and that quantum processes in the brain could explain consciousness.

between the theories is that GNWT defines consciousness as a message, whereas ITT defines it as a special kind of structure," explains Prof Giulio Tononi, a neuroscientist at the University of Wisconsin and one of the founders of ITT.

The first experiment is led by Prof Lucia Melloni at the Max Planck Institute for Empirical Aesthetics, and following the principles of open science, is entirely preregistered (this means that all the methods and hypotheses are declared in advance and made public). Due to run for three or four years, the experiment will involve volunteers looking at various task-relevant and task-irrelevant stimuli and playing video games while their brain activity is recorded by multiple methods, including magnetoelectroencephalography, functional magnetic resonance imaging and invasive intracortical recordings. It's hoped the patterns of neural activity recorded in different states of conscious awareness will provide decisive evidence in favour of ITT or the GNWT – as agreed by the leaders of those theories. For instance, GNWT predicts consciousness will be correlated with activity in the frontal and parietal regions of the brain as information is broadcast to specialist modules, whereas ITT predicts the back of the brain will be more relevant to consciousness since it has the necessary structural properties.

"I am optimistic that IIT will not fare too badly," says Tononi. "But I also hope to learn something none of us expected, which is often a wonderful bonus of science."

In the further yet-to-be-agreed experiments, other theories to be tested include so-called higher-order theories, predictive coding theories and quantum theories (see box, previous page).

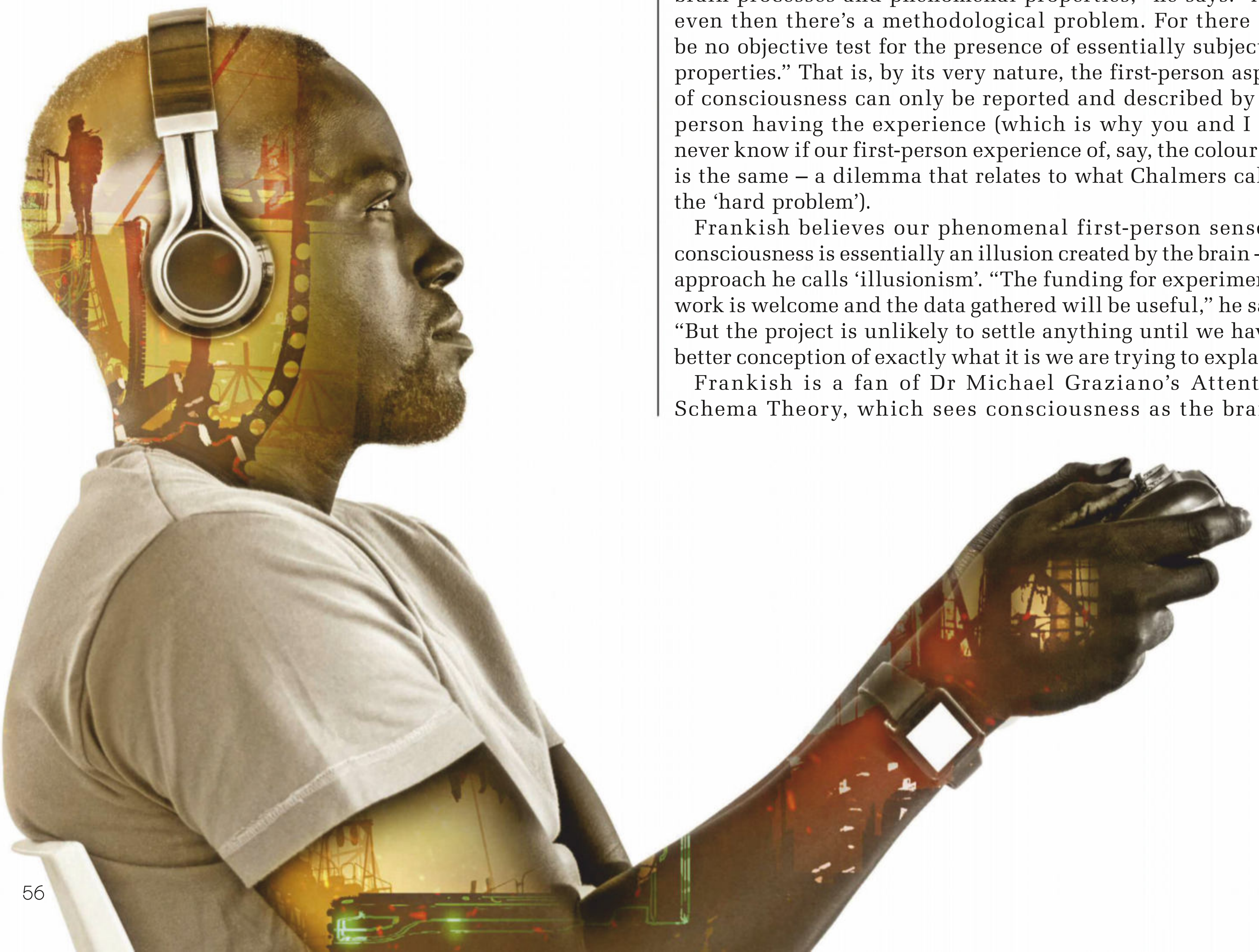
MIXED REVIEWS

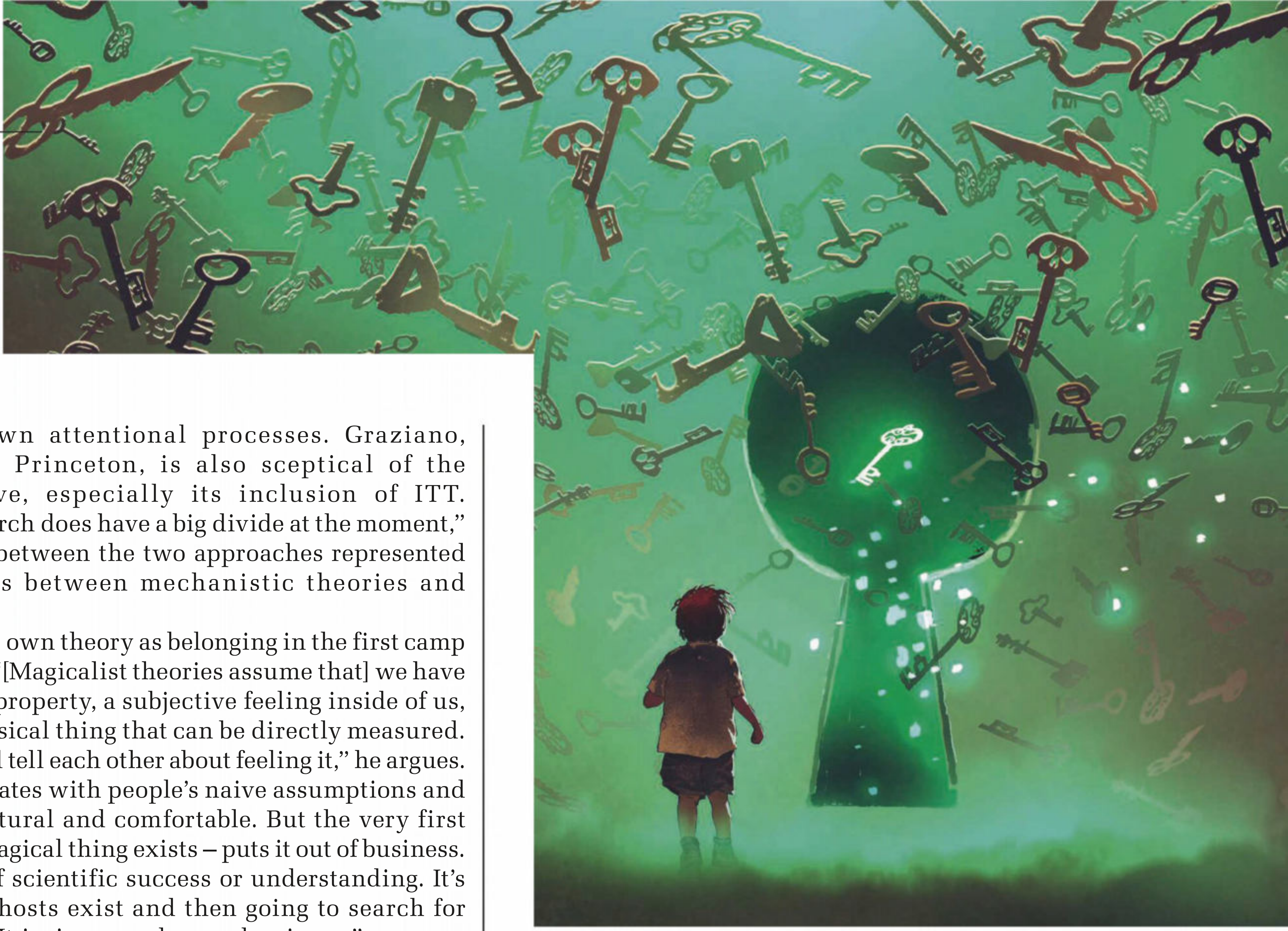
Not everyone is completely enthusiastic about the new initiative. Take Dr Keith Frankish, a philosopher at the University of Sheffield, who is sceptical about any theories that claim to explain our subjective or 'phenomenal' sense of consciousness (the 'what it feels like' aspect) in terms of brain processes.

"The most we can hope to do is to find correlations between brain processes and phenomenal properties," he says. "And even then there's a methodological problem. For there can be no objective test for the presence of essentially subjective properties." That is, by its very nature, the first-person aspect of consciousness can only be reported and described by the person having the experience (which is why you and I can never know if our first-person experience of, say, the colour red is the same – a dilemma that relates to what Chalmers called the 'hard problem').

Frankish believes our phenomenal first-person sense of consciousness is essentially an illusion created by the brain – an approach he calls 'illusionism'. "The funding for experimental work is welcome and the data gathered will be useful," he says. "But the project is unlikely to settle anything until we have a better conception of exactly what it is we are trying to explain."

Frankish is a fan of Dr Michael Graziano's Attention Schema Theory, which sees consciousness as the brain's





modelling of its own attentional processes. Graziano, a neuroscientist at Princeton, is also sceptical of the Templeton initiative, especially its inclusion of ITT. “Consciousness research does have a big divide at the moment,” he says. “But it isn’t between the two approaches represented in this project. It is between mechanistic theories and magicalist theories.”

Graziano counts his own theory as belonging in the first camp and ITT in the latter. “[Magicalist theories assume that] we have an essentially magic property, a subjective feeling inside of us, that is itself not a physical thing that can be directly measured. We can only feel it and tell each other about feeling it,” he argues. “This approach resonates with people’s naive assumptions and intuitions, so it is natural and comfortable. But the very first assumption – that a magical thing exists – puts it out of business. There is no chance of scientific success or understanding. It’s like assuming that ghosts exist and then going to search for them ‘scientifically’. It is, in a word, pseudoscience.”

Graziano has more time for the GNWT, but he believes versions of it also flirt with a magicalist approach and, by choosing to pitch this theory against ITT, he sees the Templeton initiative as doomed from the start. “It’s too bad so many researchers are still trying to find the ghost in the machine instead of trying to understand why the machine thinks there’s a ghost in the first place,” he says.

MOVING FORWARD

Potgieter has encountered many of these strong opinions in the field – indeed it’s partly what motivated him to try to use adversarial collaboration to move things forward. For instance, as counterpoint to the strong Frankish-Graziano perspective, consider the British philosopher Dr Galen Strawson’s view, expressed in the *New York Review Of Books* in 2019, that illusionism is the “silliest claim ever made”.

Given this academic climate, while the TWCF project is ostensibly about consciousness theories, ultimately its aims are far deeper – to change the way science is done. “In a way this is a stretch goal exercise and we try to achieve something, and we learn a lot of things that we can then apply to just raise the standard of science more generally … so hopefully it works but I’m not worried if it doesn’t,” says Potgieter.

“Our interest is as much in cultural change as it is in the formal outcome of killing a theory,” adds Potgieter’s boss, Dr Andrew Serazin, the president of the Templeton World Charity Foundation. According to Serazin, early signs are good.

“What has been most inspiring about the process has been the dedication, professionalism, and genuine idealism of the scientists who have spent already the best part of a year … making this project come to life,” says Tononi. “If one puts this together with the enthusiasm and willingness to participate demonstrated by several busy experimentalists all over the world, one cannot help but feel optimistic about the possibility for scientific progress, even on a problem as difficult and misunderstood as consciousness.” SF

> “ONE CANNOT HELP BUT FEEL OPTIMISTIC ABOUT THE POSSIBILITY FOR SCIENTIFIC PROGRESS, EVEN ON A PROBLEM AS DIFFICULT AND MISUNDERSTOOD AS CONSCIOUSNESS”

by **DR CHRISTIAN JARRETT**

Christian is a psychologist and senior editor at Aeon. His next book about personality change is due for release in 2021.

GETTY IMAGES X2

THE WEIGHTLESS BRAIN

With commercial spaceflight on the horizon, scientists are racing to understand what being off-Earth will mean for the human body. Psychologist **Dr Elisa Raffaella Ferrè** *wants to know how gravity, or a lack thereof, will change the way we think.*

She speaks to **Amy Barrett**

Photography: **Andrew Cotterill**

YOUR WORK LOOKS AT THE INFLUENCE OF GRAVITY ON THE BRAIN. WHY DO WE NEED TO STUDY THIS?

This is a very good and timely question. Last year was the 50th anniversary of the Apollo Moon landing. Fifty years ago we had brave people going into outer space without even knowing what they were doing, and they coped with that. They did an amazing job. But we are at the beginning of a new space age. NASA will send astronauts to Mars in 20 years, and commercial space flight is going to be a reality. Soon, you'll be able to buy a ticket to go to outer space, enjoy your travel, and come back. The experience of being in outer space is fascinating, but it's not easy for our bodies and our brains to deal with non-terrestrial gravity. Understanding how gravity can impact our brain is necessary before we go in that direction.

WHEN WE'RE ON EARTH, IS GRAVITY HAVING AN IMPACT ON OUR BRAIN IN WAYS THAT WE DON'T REALISE?

Yeah. The impact of gravity on human cognition is still neglected in psychology and neuroscience. We have been focused on a lot of other aspects of our cognition, like how we recognise colour and how good we are at perceiving sounds.

Gravity is a sensory signal. Earth's gravity is a constant acceleration of 9.807m/s^2, namely 1g. But we cannot 'feel' it. You can see a colour, you can hear a song, you can spot a mosquito on your skin, but you don't perceive gravity. Yet gravity is the most persistent sensory signal in the brain and it silently contributes to lots of different things in our daily lives, like walking, jumping, lifting objects, whatever.

We have evolved in a terrestrial environment under a stable 1g acceleration. The vestibular otoliths, which are tiny, sophisticated receptors inside the inner ear, constantly monitor the magnitude and direction of gravitational acceleration. The importance of gravity for behaviour is evident when we are in a place in which there is not the usual gravitational acceleration, such as outer space. In weightlessness, the human brain has to adapt and cope with the fact that familiar 1g is no longer there. That's why it's not so easy to be in outer space. Astronauts often report the so-called 'space motion sickness'. Imagine the worst carsickness you've had, and now multiply it by 10 or even more. Here we are! This is caused by the absence of gravity: the brain takes time to adjust to a novel gravitational environment.

THIS IS A YOUNG FIELD OF STUDY, ISN'T IT?

It is, and it's a very unusual field of research. Compared to other sensory modalities, our knowledge of gravity as a perceptual signal has not advanced so much. The reason is very simple. It's not easy to study the contribution of gravity on Earth, where gravity is always there.

EXACTLY. HOW DO YOU DO IT?

We need to be creative in finding ways to study gravity on, and possibly outside, Earth. Fantastic medical research is constantly done on the International Space Station [ISS]. Astronauts are engaged in several experiments – do you remember how busy Tim Peake was? – providing direct data on the effects of gravity on bodily physiology. However, we are talking about a few people who are extremely well trained to be in outer space. What I'm more interested in is what happens to non-astronauts when exposed to non-terrestrial gravity.

My research combines techniques from cognitive neuroscience and experimental psychology with space research methods. We run experiments supported by the European Space Agency [ESA] on parabolic flight – the famous 'Vomit Comet' – and human centrifuges. We are also developing techniques to alter gravity in our lab, allowing us to understand how gravity impacts behaviour in large groups of people here on Earth.

We use inversion tables, which can passively turn people upside down. We also recently demonstrated that virtual reality can be reliably used to trick the brain and make people believe that they are on planet with different gravity, on Mars for example. And finally, we apply artificial vestibular simulation, in which some electrodes placed behind the ear electrically stimulate the vestibular nerve [which is responsible for hearing and balance]. It looks a little bit *Frankenstein*, but it's totally safe, don't worry. Using these methods, we can study how perception and cognition change when gravitational information is altered.

YOU'VE MENTIONED PARABOLIC FLIGHT – CAN YOU BRIEFLY EXPLAIN WHAT THAT IS?

This is the real fun part of my research! Parabolic flights are done on a refitted A310 Airbus plane. There are not the usual seats, but there is experimental equipment. Multiple

▶

DR ELISA RAFFAELLA FERRÈ

Elisa is a senior psychology lecturer and the director of the Vestibular Multisensory Embodiment (VeME) lab at Royal Holloway, University of London. Her work has taken her from the lab into the skies with parabolic flights, and in more unusual directions through collaborations with artists, musicians and the Guerilla Science YouTube channel's *Space Yoga* series.

> "Astronauts often report the so-called 'space motion sickness'. Imagine the worst carsickness you've had, and now multiply it by 10"

teams are onboard at the same time, and experiments can vary from the biological sciences to physics.

During these flights, the plane follows the trajectory of a parabola. It alternates between rises and descents, at a 45° angle of inclination. Each parabola starts with a ‘pull-up’ acceleration phase in which the gravitational load is double Earth’s gravity, what we call hypergravity or 2g. The pilots then let the aircraft drop into ‘free-fall’. This phase generates weightlessness (0g). Then pilots perform a ‘pull-out’ acceleration, in which gravity is again double. Each phase lasts for approximately 20 seconds.

During the flight we’ll have many parabolas, around 15 or 16, so the flight itself lasts for two or three hours. It’s a long period of time, but the experiment can only last 20 seconds because of the short exposure to microgravity.

CAN YOU ACHIEVE ANYTHING IN JUST 20 SECONDS?!

It’s complicated, but it’s doable. The experiment needs to be well designed, precise, and controlled. We have to make sure that the experiment is perfect before take-off. Then it’s kind of a dance, a choreography of people doing stuff for the experiment in those 20 seconds, in approximately 1.5m^2 of space, and while floating. So, it’s challenging. It’s far from the comfort of the lab, but the experience of weightlessness itself is already a nice reward!

WHAT DOES IT FEEL LIKE?

Weightlessness is the best thing ever. It’s awe and freedom. Movements are with no effort, no physical constraints, floating. It’s an amazing experience. But, let me be honest: it is not easy. I mentioned before space motion sickness and we get it during parabolic flights. We normally have some medication, but there is sickness and disorientation.

WHAT EFFECT HAVE YOU FOUND THAT GRAVITY HAS ON COGNITION?

My research group and I are interested in how gravity influences human perception and decision making. For instance, we wanted to see whether decision making is optimal when gravity is no longer our usual 1g acceleration.

We did that in the lab, actually, by asking people to say a random number. You are going to say, ‘How is this related?’ Well, [when you say a series of random numbers] you either you go with the same option, generating ‘stereotype behaviour’. For instance I’d keep saying ‘two’, ‘two’, ‘two’. Or you shift from one number to another, kind of generating ‘optimal behaviour’. So more options, more novel behaviour. Now, when we think about adaptations to the environment, we want to have a trade-off between stereotype and novel. We don’t always want to go for the same choice, we don’t always want to go for a different choice.

This sort of random number generation task can give us some indexes of how willing and exploring people are in an environment. We did this with participants being upright, in line with the orientation of gravity, or lying down flat, a posture incongruent to gravity. This simple manipulation allowed us to alter the physiological processing of gravity, leading to very different gravitational information reaching our brain. The vestibular organs immediately detect ‘I’m not aligned with gravity’.

We found that, while lying down, people were producing more stereotyped responses. This tells us that participants were not using an optimal strategy to solve the task and that their decision-making was affected by altered gravity. Now, this is a lab experiment. But imagine that you are on Mars. You need to decide whether to explore or to stay put. Maybe exploring is risky, but you need to do it, and if you don’t move, you don’t explore, this might be a problem.

Our lab manipulation is basically telling us, look, people might not take the right decision

ABOVE LEFT Elisa on board the Vomit Comet

ABOVE RIGHT On firmer ground at Royal Holloway, University of London

> “Weightlessness is the best thing ever. It’s awe and freedom. Movements are with no effort, no physical constraints. It’s an amazing experience”

when they are away from the home port of terrestrial gravity, which I think might have some implication.

HOW WOULD YOU OVERCOME THAT?

Hopefully with some good training. Indeed, I’m not expecting to see this sort of impairment in astronauts: as I say, they undergo substantial training before going to outer space. I’m thinking more of a commercial space flight; we’ve bought the ticket, then we want to go on the plane. We really don’t want two years or four years of training before going on our vacation. This scenario requires good training programmes to ensure that potential space travellers are able to make optimal decisions if needed.

IT SEEMS TO BE MOVING FASTER THAN THE SCIENCE IS MOVING. IS THAT RIGHT?

It looks so. I think we have achieved amazing results in the past years regarding technical improvements in space exploration. But we also need to put some effort into understanding how we can improve human performance. I’m not pessimistic; I’ll just say there’s an issue and we need to solve it.

SO, WHAT’S NEXT?

This is a challenging field, but it’s so open to the ‘what’s next’ question: there are so many aspects that we can potentially investigate. We are currently looking at how altered gravity affects risk-taking and social interactions. But we are also doing some research on low-level sensory processing, and we have just finalised a research study on whether pain perception is influenced by altered gravity.

PAIN CAN BE AFFECTED BY GRAVITY?

This is not yet published, as we have just finished it, but yes, altered gravity seems to make people feel less pain, a sort of analgesic effect.

IF YOU WERE OFFERED A TICKET ON A COMMERCIAL SPACEFLIGHT RIGHT NOW, WOULD YOU GO?

Absolutely yes! Of course I would go.

IF YOU HAD THE CHOICE TO GO ANYWHERE IN SPACE, WHERE WOULD YOU GO?

The Moon.

YOU SAID THAT SO QUICKLY, YOU ALREADY KNEW YOUR ANSWER. WHY THE MOON?

I always feel emotional when I see the videos of the Moon landing. I’m too young to have seen it live, unfortunately, but I think it was always impressive for me to see that footage.

We spot the Moon from Earth almost every night. Can you imagine how beautiful it might be seeing our planet, Earth, from there? It will give us an awareness of how beautiful, yet delicate and fragile, our Blue Marble is.

DO YOU THINK WE’LL EVER BE ABLE TO COLONISE SPACE? THAT WE’LL EVER BE ABLE TO LIVE OUTSIDE OF EARTH?

Possibly. Our brain is fantastic at adaptation. Think about on Earth, where people have managed to live in a lot of challenging environments; in the desert, on the peak of a mountain. Space is the ultimate frontier. It is not going to be easy, much harder than what we see in science fiction movies, but yes. Why not? SF

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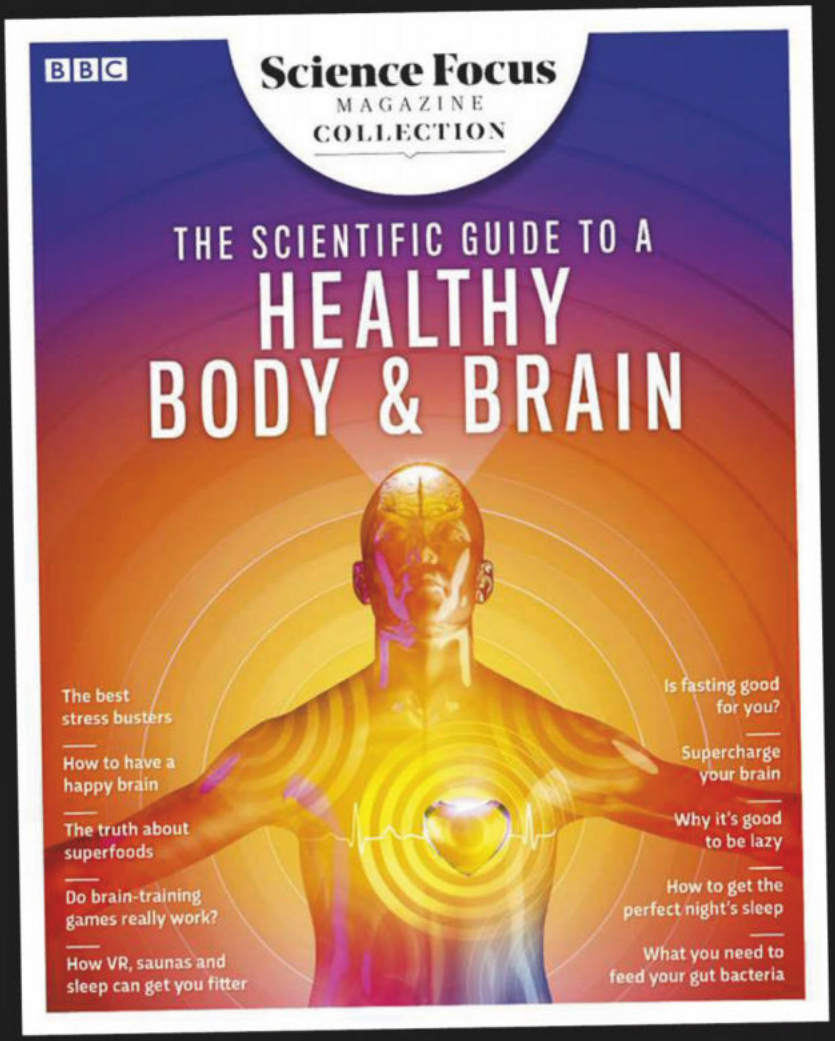

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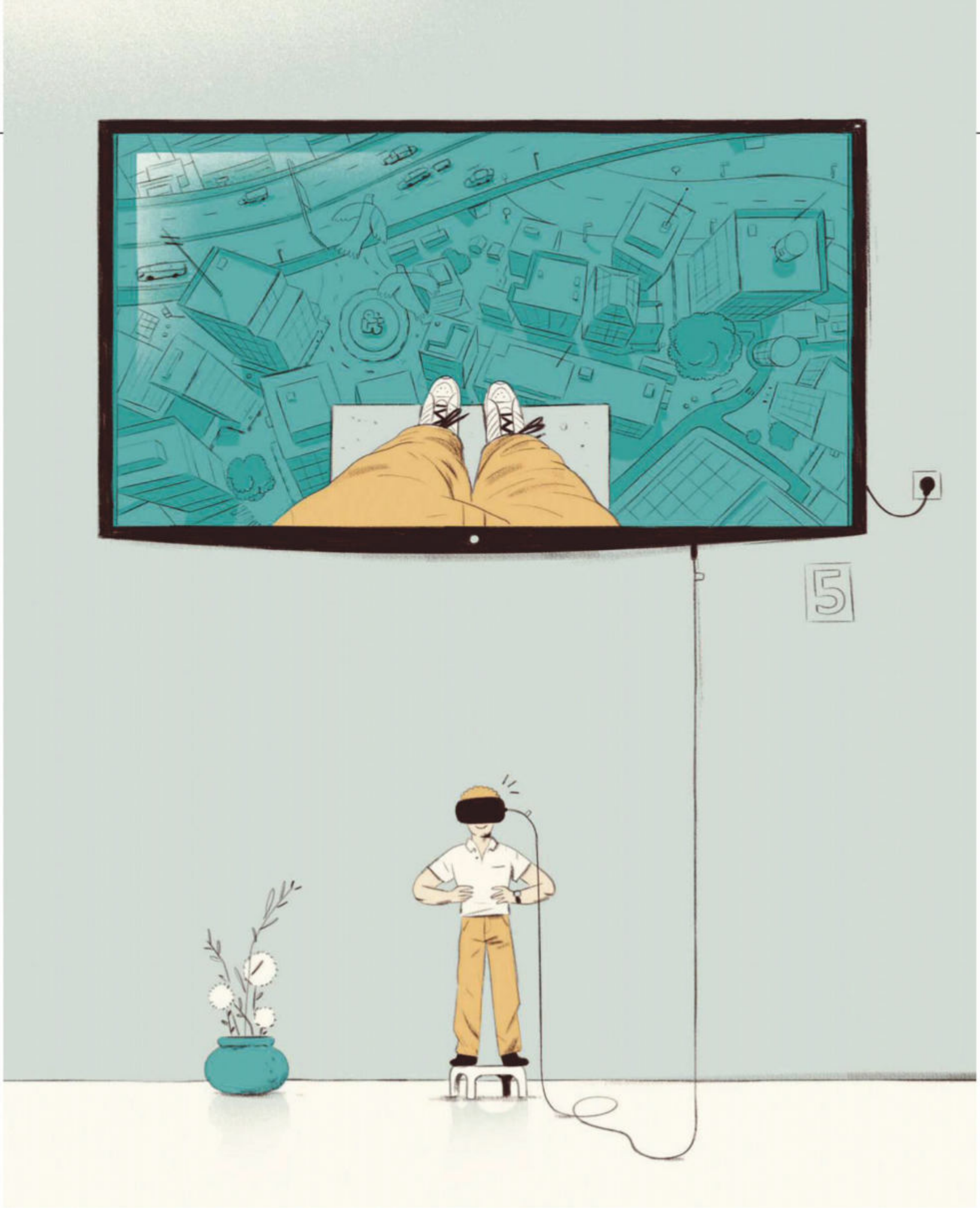
COMMENT

FACE YOUR FEARS

Could virtual reality treatment help cure people of their phobias?



Over the years I've taken part in some crazy self-experiments, ranging from infecting myself with a tapeworm to prolonged sleep deprivation. But the worst was a film I made on fear, during the course of which I agreed to go caving. I am mildly claustrophobic, so when I got stuck deep underground I almost screamed the cave down. This delighted the director, but it was the most frightened I have ever been.

So I was sympathetic when one of my co-presenters on *Trust Me, I'm A Doctor*, psychiatrist Dr Alain Gregoire, admitted to having a fear of heights. This phobia affects around 20 per cent of people in the UK.

The traditional way of treating phobias is by exposing yourself to the thing you fear in a controlled way. So I was surprised when I heard Alain was going to try and crack it using virtual reality (VR). But I later discovered there is solid evidence that VR can be effective. In a trial carried out by researchers from Oxford University and published in *The Lancet* in 2018, 100 people with a fear of heights were randomly allocated to receive either no treatment, or six sessions of VR intervention over two weeks.

Those in the second group wore a VR headset that allowed them to explore a virtual environment where they could carry out tasks like looking over the ledge of a 10-storey building, or walking onto a platform to rescue a cat in a tree. While they were doing these activities, a virtual therapist talked to them about their fears.

> **"Although I knew I was standing in a grey, carpeted room, I was soon sweating and frightened"**

The volunteers had to fill in surveys that scored their fear of heights before and after the treatment, and then again at four weeks. "Everyone who had the VR treatment benefited to some extent," said Prof Daniel Freeman, who led the trial. "The average reduction in fear of heights was 68 per cent. So down by two-thirds, which is a large clinical effect."

But would it work for Alain? With trepidation he donned the headset and entered a 3D virtual world. "It felt incredibly real," he later explained. "Although I knew that I was standing in a grey, carpeted room with a flat floor, I was soon sweating, anxious and frightened. My legs began shaking and I developed pains in my chest as they asked me do a series of tasks at ever greater 'heights'."

But he found he could live with the fear and his symptoms improved. When he was later challenged with a real situation where he had to look over a big drop, he was surprised to find that he could do it. "Throughout my career I've believed it takes a long time to make significant psychological changes. Yet this brief intervention definitely worked for me."

VR therapy is now offered on the NHS in some parts of England and is also being trialled for other conditions like obsessive compulsive disorder (OCD). When they come up with a VR world that can treat claustrophobia, I might just give it a go. **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. The new series is out now.

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: OVADIA BENISHU

COMMENT

A MAGICAL PLACE

Theme parks use clever techniques to make your visit memorable – and all without forcing you to download an app or check in online

Theme parks? I'm a sucker for them. In a month or so, the UK's finest will throw their gates open for the new season to thrill us with their engineered delights. As usual, I will be the first person inside, forced to sit through pre-shows, until I plunge like a lemming into wilful surrender. Yes, I may be a digital evangelist, but to me there is nothing as compelling or as intoxicating as the full-on experience of spending a day in someone else's imagination.

Dr Carissa Baker, assistant professor in theme parks and storytelling at the University of Central Florida, argued in 2018 that theme parks are gatherers and tellers of stories. Their distinct narratives start before you enter the park, are played out in what you experience there, and continue after you've left. They enrobe us in myth, folklore or film – depending on where in the world you're visiting – and uniquely extend that world by putting us right in the middle of it. How do they do it? Some believe it's down to creative direction and narrative system design. But I call it like I see it: they use all the psychological tricks in my social psychology textbooks to get us to feel and act in the way that the people behind the scenes foretell. And then some.

Everything in theme parks is manipulated. Everything is accounted for. Whereas in the digital world, designers infer what we feel, these theme parks incept these emotions. A famous example is Disneyland's Main Street USA, which you walk down on first entering the park: the sets have been designed with forced perspective so the buildings appear taller and grander than they are. Techniques like this abounded in the squares of Renaissance Italy and Georgian England to make the buildings seem bigger than they were. The mythical Main Street is made to feel larger and more impressive than it really is, which gets visitors excited when they enter the park – we are the hero of Disneyland's narrative. Now that's a powerful trick.

> **"The next killer app isn't on your device. It's in the places that compel us to keep our phones in our pockets"**

The digital world is nowhere near as magical as these places are. Yes, digital designers can create something out of nothing with mathematics and electricity, but their best attempts are only shortcuts in two-dimensional space. All they have in their toolboxes are sight and sound. Mystifyingly, they've still magicked us into thinking they've been able to recreate human emotions while harvesting our humanity.

But in theme parks, digital is out of place. Yes, behind the scenes there are data machines that are trying to track us to make our experiences better and more personal. Except for one or two notable examples, digital tech isn't being used to enhance our time at the park in any practical way. It just gets in the way. And perhaps that is why I love theme parks. Because when I'm there, I want to be propelled by someone else's vision, and give over to the feeling.

The next killer app isn't on your device. It's in the places that thrill us and compel us to keep our phones in our pockets so we can truly experience them. **SF**

ALEKS KROTOSKI
Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

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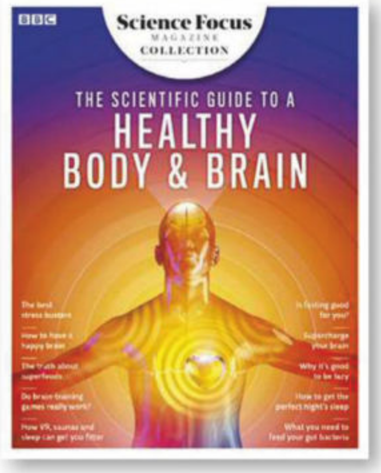

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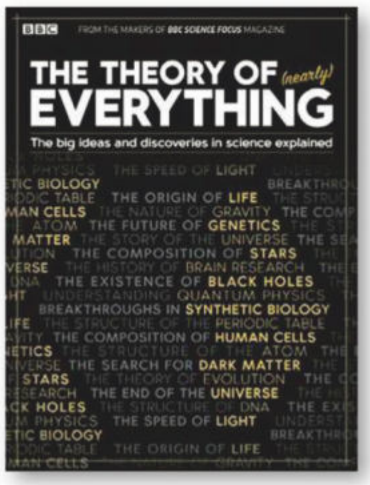

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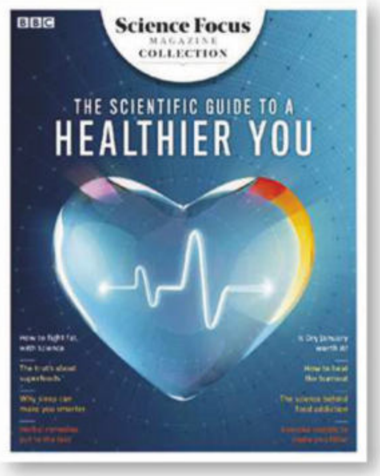

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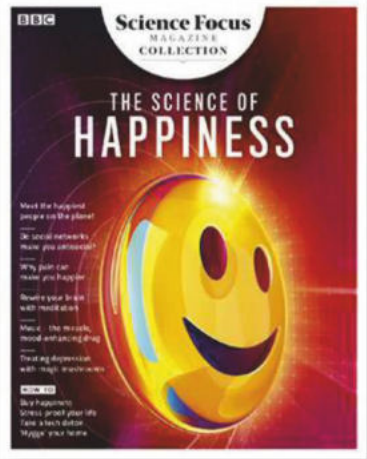

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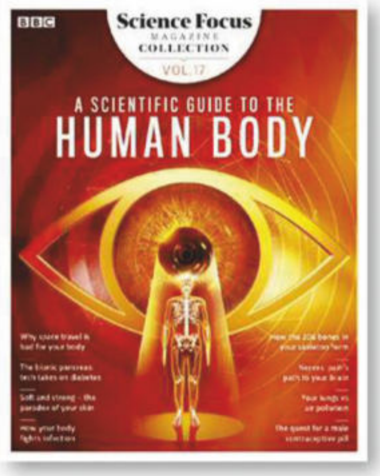

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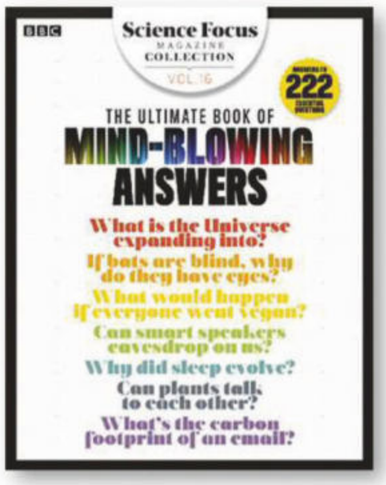

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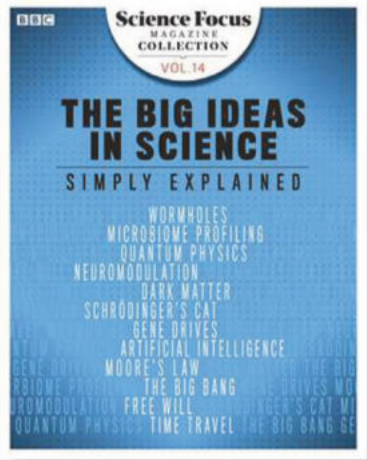

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CHASING COMETS

These enigmatic, icy travellers may hold the secret to life on Earth. That's why scientists are designing a mission that will pay a visit to a comet to take a closer look...

by **DR STUART CLARK**

We've come a long way since thinking that comets were ghostly apparitions in the sky that foretold disaster and disease. Now we understand that these mysterious celestial objects are time capsules to an earlier era in the history of the Solar System. They can tell us about the days when the planets were forming. Comets can also reveal some of the chemical constituents that would have been present on the early Earth and so could have contributed to the origin of life.

It's therefore no surprise that the various space agencies around the world are keen to explore comets with spacecraft. Currently under development is Comet Interceptor, which is due for launch in 2028 and will allow us to inspect these icy bodies in greater detail. But it's by no means the first mission to visit a comet.

In 1986, Europe, the USSR and Japan launched missions to fly past Halley's Comet. Of these, the spacecraft that drew the closest was the Giotto mission, from the European Space ➤

The Philae lander was part of the Rosetta mission. It touched down on comet 67P/Churyumov-Gerasimenko in 2014, as seen in this illustration

Agency (ESA). It gave us the first image of a comet's icy nucleus and showed that gas was shooting into space from jets on the surface.

ESA's more recent comet mission, Rosetta, rendezvoused with the comet 67P/Churyumov-Gerasimenko, and followed it for two years between 2014 and 2016. It revealed unprecedented information about how a comet behaves as it draws close to the Sun, and then heads into deep space again. One thing became very clear. "There are a lot of evolutionary processes taking place on the surface layers of a comet. The surface actually changed as we were watching with Rosetta," says Dr Colin Snodgrass, an astronomer from the University of Edinburgh who was part of the Rosetta team.

They watched as areas were eroded away, while others were buried in material falling back to the surface. "We always knew that comets eroded but the extent to which they changed each time they passed the Sun was something that we really learned from Rosetta," says Snodgrass.

THE REAL ROCK STARS

That's both good and bad news for astronomers. While it means that we know more about how a comet works than ever before, it also tells us that their surfaces are not a pristine record of the original planetary building blocks. All of the comets we have visited so far are called short-period comets. They are ancient objects that formed in the outer reaches of the Solar System, beyond the giant planets, and have since fallen into closer orbits around the Sun. Here they have been periodically sunblasted and altered, perhaps beyond recognition from their original states.

Thankfully, for helping us understand how the planets formed, there is another class called the long-period comets. These are on gigantic orbits. In 1997, comet Hale-Bopp appeared in our skies and was visible to the naked eye for 18 months. Based on its current orbit, it may have last been close to Earth around 4,200 years ago. A year before, in 1996, comet Hyakutake passed by on an orbit that will take around 70,000 years to complete. All of these comets have surfaces that must be much closer to their pristine states.

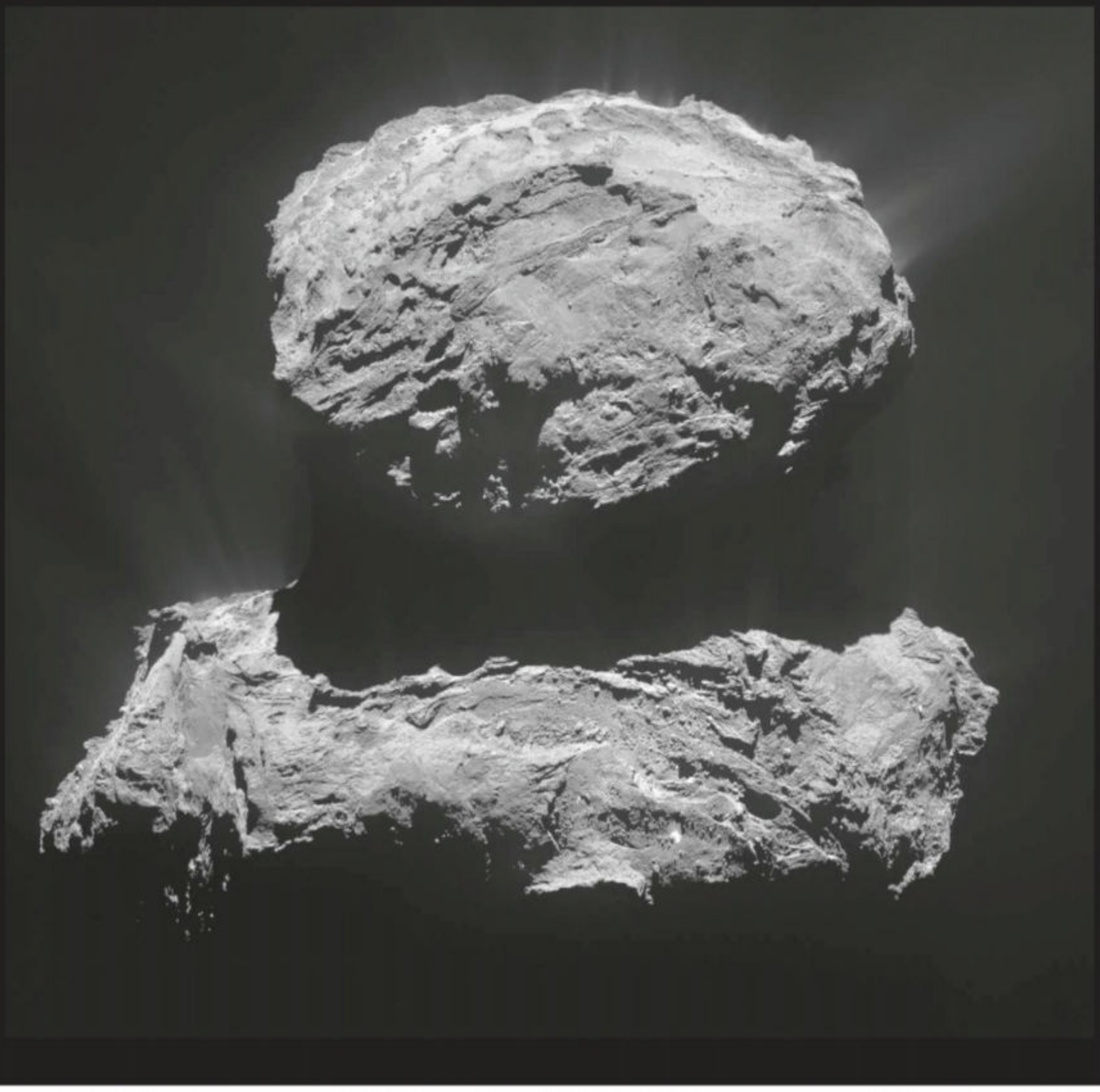
There is also the occasional comet that falls back towards the Sun for the first time. These are the ones we really need to look at if we are going to unlock the secrets of the early Solar System. As well as being pristine, astronomers think that they originally formed between the giant planets, making them much more representative of the actual building blocks that made up the planets in the first place. Gravitational interactions with the newly formed planets then threw them out to vast distances, where the intense cold has preserved them.

If we could see one up close, it would be an opportunity to examine a completely different region of the early Solar System. But we never know when they are coming, and spacecraft take the best part of a decade to design and build, by which time the comet has been and gone. So, how will we ever get to see one up close?

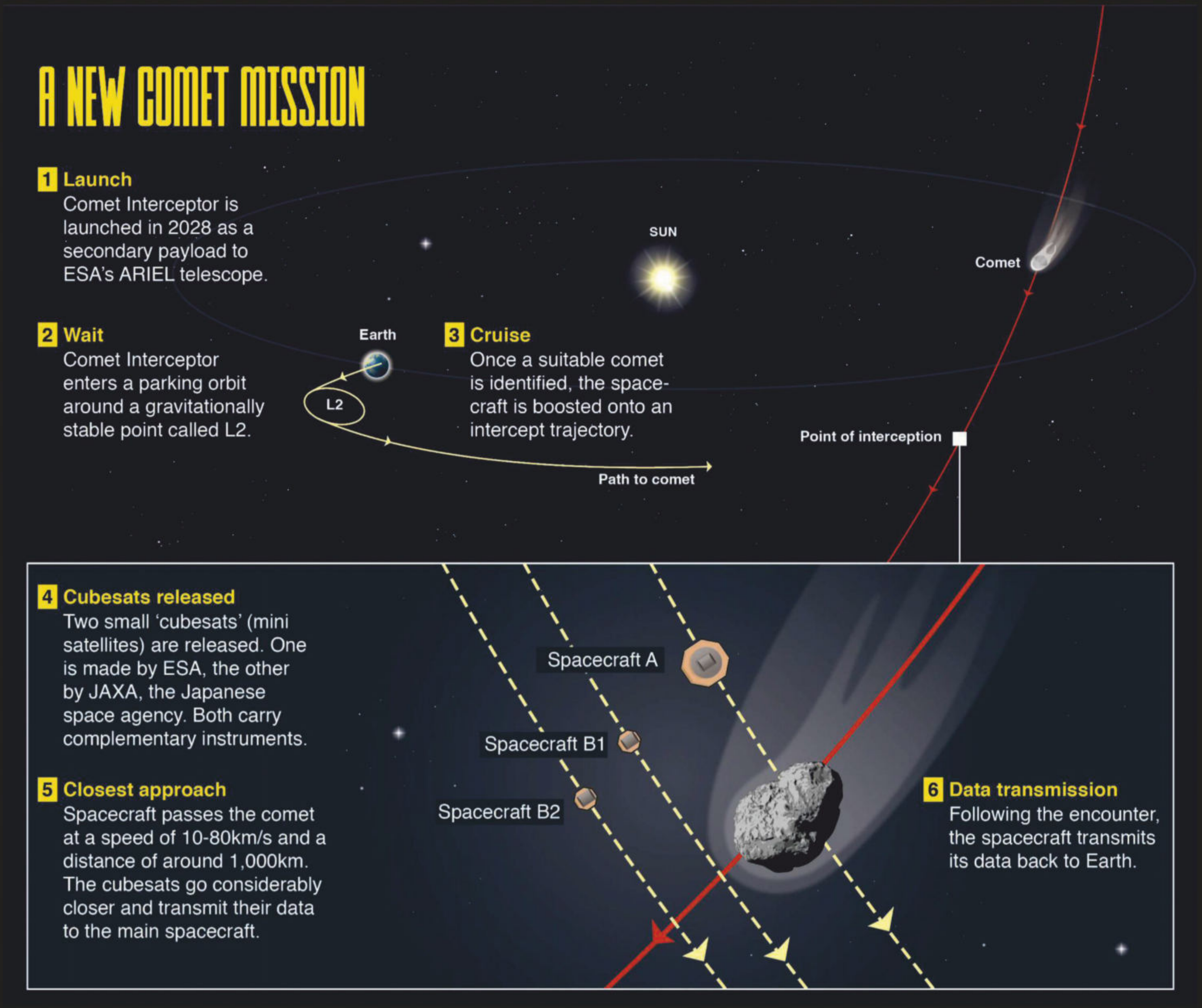
That's where Comet Interceptor comes in. ESA

"THE SURFACE OF THE COMET ACTUALLY CHANGED AS WE WERE WATCHING WITH ROSETTA"

BELOW The dumbbell shape of comet 67P/Churyumov-Gerasimenko is the result of fusion between two comets, captured here by the Rosetta mission in 2015



A NEW COMET MISSION



1 Launch
Comet Interceptor is launched in 2028 as a secondary payload to ESA's ARIEL telescope.

2 Wait
Comet Interceptor enters a parking orbit around a gravitationally stable point called L2.

3 Cruise
Once a suitable comet is identified, the spacecraft is boosted onto an intercept trajectory.

4 Cubesats released
Two small 'cubesats' (mini satellites) are released. One is made by ESA, the other by JAXA, the Japanese space agency. Both carry complementary instruments.

5 Closest approach
Spacecraft passes the comet at a speed of 10-80km/s and a distance of around 1,000km. The cubesats go considerably closer and transmit their data to the main spacecraft.

6 Data transmission
Following the encounter, the spacecraft transmits its data back to Earth.

ESA ILLUSTRATION: ACUTE GRAPHICS

has given Snodgrass the funding, and he and Prof Geraint Jones from University College London will mastermind the mission. Comet Interceptor will launch in 2028 and will wait in space until a target comet is found. Designing and planning the mission will be unique, however, as there isn't a specific comet in mind. "No one has ever designed a mission without a first idea of what the target is. This is very uncharted territory," says Snodgrass.

A space mission usually has a specific target, and that allows engineers to calculate the optimum trajectory, and therefore how much fuel will be needed, which tells them the size of the fuel tanks, which tells them how much mass is available to use for the scientific instruments. In other words, the target defines the spacecraft.

The proposed encounter also allows the design team to figure out the optimum place to put the solar panels and the instruments. None of these things are known for Comet Interceptor. The team does not know what direction they will approach their target from, how far from the Sun the comet will be, or how far from the Earth. So they have to design an extremely flexible mission.

LET'S GET ASTROPHYSICAL

Comet Interceptor will take images of its comet's surface at comparable quality to those that Rosetta took of comet 67P, and it will look at the differences in composition between the two comets. "We expect the chemical makeup of such comets to be potentially very different from 67P-like comets," says Prof Stephen Lowry, a comet expert from the University ►

INTERSTELLAR VISITORS

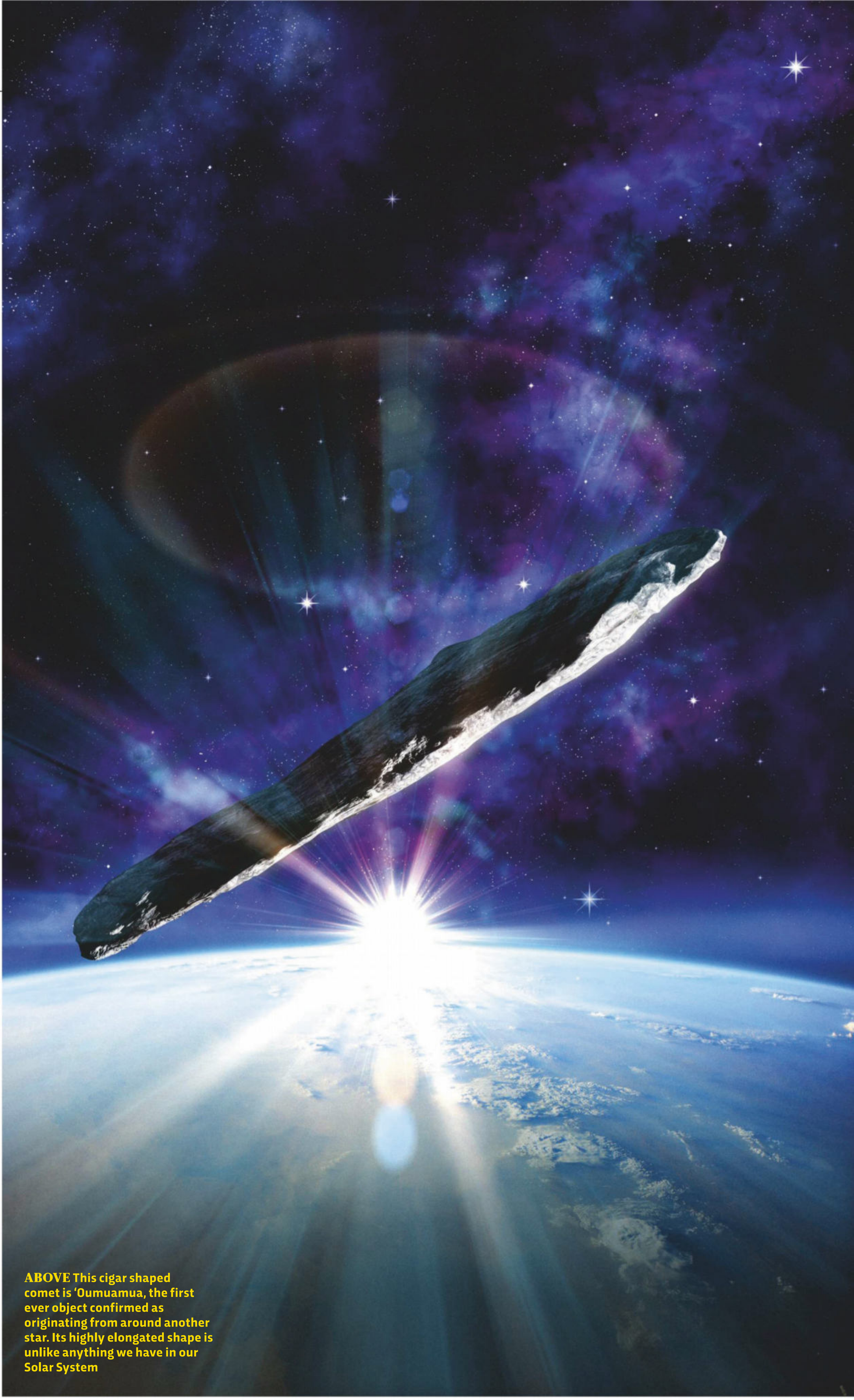
In 2017, astronomers identified a comet from a completely different solar system passing through our own. Discovered by the Pan-STARRS telescope at Haleakala Observatory, Hawaii, it was called ʻOumuamua, the Hawaiian word for 'scout'. At first, it looked like an asteroid because it did not display tails like a comet, nor a surrounding gas cloud known as a coma.

But later, it began to accelerate in a way that could not be described by the gravitational pull of the Sun or the planets. Although this led to some lurid headlines about it being an alien spacecraft, such behaviour is precisely what comets do. It occurs because the heat from the Sun releases gas from the ices below the comet's surface, and the escaping gas acts like a small rocket motor.

In 2018, another interstellar comet was identified cruising through the Solar System. Called Borisov, it made its closest pass to the Sun in December 2019 and was estimated to be losing two kilograms of dust and 60 kilograms of water every second.

The idea of using Comet Intercepter to see something from another solar system is clearly tantalising for the science team, but they are also realistic about their chances of actually targeting one.

"It's a pretty remote chance to be quite honest," says Dr Colin Snodgrass, an astronomer from the University of Edinburgh. This is because we have no idea how frequently they pass by. It may simply be blind luck that we have identified two in as many years. Astronomers will know more when the Large Synoptic Survey Telescope (LSST) begins work in 2022.



ABOVE This cigar shaped comet is ʻOumuamua, the first ever object confirmed as originating from around another star. Its highly elongated shape is unlike anything we have in our Solar System

> **"TAKING A PIECE OF A COMET BACK TO EARTH IS THE HOLY GRAIL FOR A COMETRY MISSION"**

▶ of Kent. This is because they formed closer to the Sun, meaning that the warmer environment would affect the number and type of organic molecules on their surfaces.

It's not only chemistry that could be different, as the long-period comets could also reveal whether the planets formed violently or gently. "One of the top five results from Rosetta was the shape of the comet," says Lowry. Comet 67P was a dumbbell-shaped object that analysis showed was the result of a fusion between two independently formed comets. It was a big result because it showed that fully formed comets were merging in a gentle way; their collision speed must have been around walking pace. Yet, it was thought that planet formation took place much more violently. If the pattern repeats in a long-period comet, it could well mean that our ideas of planet formation as a whole need to be revised.

The search for the mission's target begins in 2022, when a bold new telescope project starts its operations. The Large Synoptic Survey Telescope (LSST) is currently under construction in Chile. With its eight-metre-wide mirror, LSST will be able to scan the whole sky every few nights. It is expected to discover hundreds and thousands more comets and asteroids in the Solar System than are currently known to exist. It could even find a target before Comet Interceptor's scheduled launch in 2028.

"We don't actually expect there to be that big a choice of target. Within the period that the mission has to operate, probably there is only going to be a handful that we can go to," says Snodgrass.

Out of that handful, there is also the possibility that they will find something truly rare: a comet from another solar system entirely. Astronomers have identified two such interstellar objects, starting with 'Oumuamua in 2017 and Borisov in 2018. Both of these objects followed trajectories that indicate that they are not bound to the Sun's gravity, and must simply be passing through the Solar System, being deflected by the Sun's gravity en route.

Although it would be almost impossible to say which star they formed around, looking at a comet close up would be a fascinating way to tell if formation processes around other stars are similar to those that took place in our Solar System.

"To actually see something that's come from another system and see how different it looks, or how similar it looks would be interesting," says Snodgrass, "If there is one we can reach, I think it would be a fairly easy decision from the science team to say, 'let's go for that'. It would be such an opportunity that you couldn't really turn it down."

UNLOCKING THE SECRET TO LIFE ON EARTH

No matter which target Comet Interceptor goes to, astronomers are already planning what to do after that. And for them, the driving question is what role comets played in the origin of life on Earth, and that comes down to doing an inventory of its surface chemistry. In particular, astronomers look for carbon-bearing molecules, often referred to as 'organic molecules' because they have become essential for life on Earth. "The composition of the organic material is really important," says Gianrico Filacchione, a comet scientist from the Institute for Space Astrophysics and Planetology (INAF-IAPS) in Rome, Italy. "There is a universe of organic compounds that need to be identified." And the only way to do that definitively is to bring a sample back to Earth and analyse it with the full force of current laboratory equipment.

To that end, Filacchione and colleagues have proposed the AMBITION mission to ESA as part of the space agency's 2050 long-term plan. If selected for development, AMBITION would land on a comet, scoop up a sample of the icy material and return it to Earth in a cryogenic capsule. "Taking a piece of a comet back to Earth is the holy grail for a cometary mission," says Filacchione.

For now, however, it is Comet Interceptor that is in the limelight. "This is an opportunity for us to go and see a comet that's coming into the Solar System for the very first time. The surface will still be looking as it has been over billions of years," says Snodgrass. But to see it requires rewriting the way space missions are designed and planned. While that will bring its own headaches, Snodgrass says he finds it more exciting than it is daunting. Although, he then adds with a touch of humour, "that's because I'm not an engineer and I don't have to make it work."

by **DR STUART CLARK**
(@DrStuClark)
Stuart is an astronomy writer. His latest book is The Unknown Universe *(£14.99, WW Norton).*

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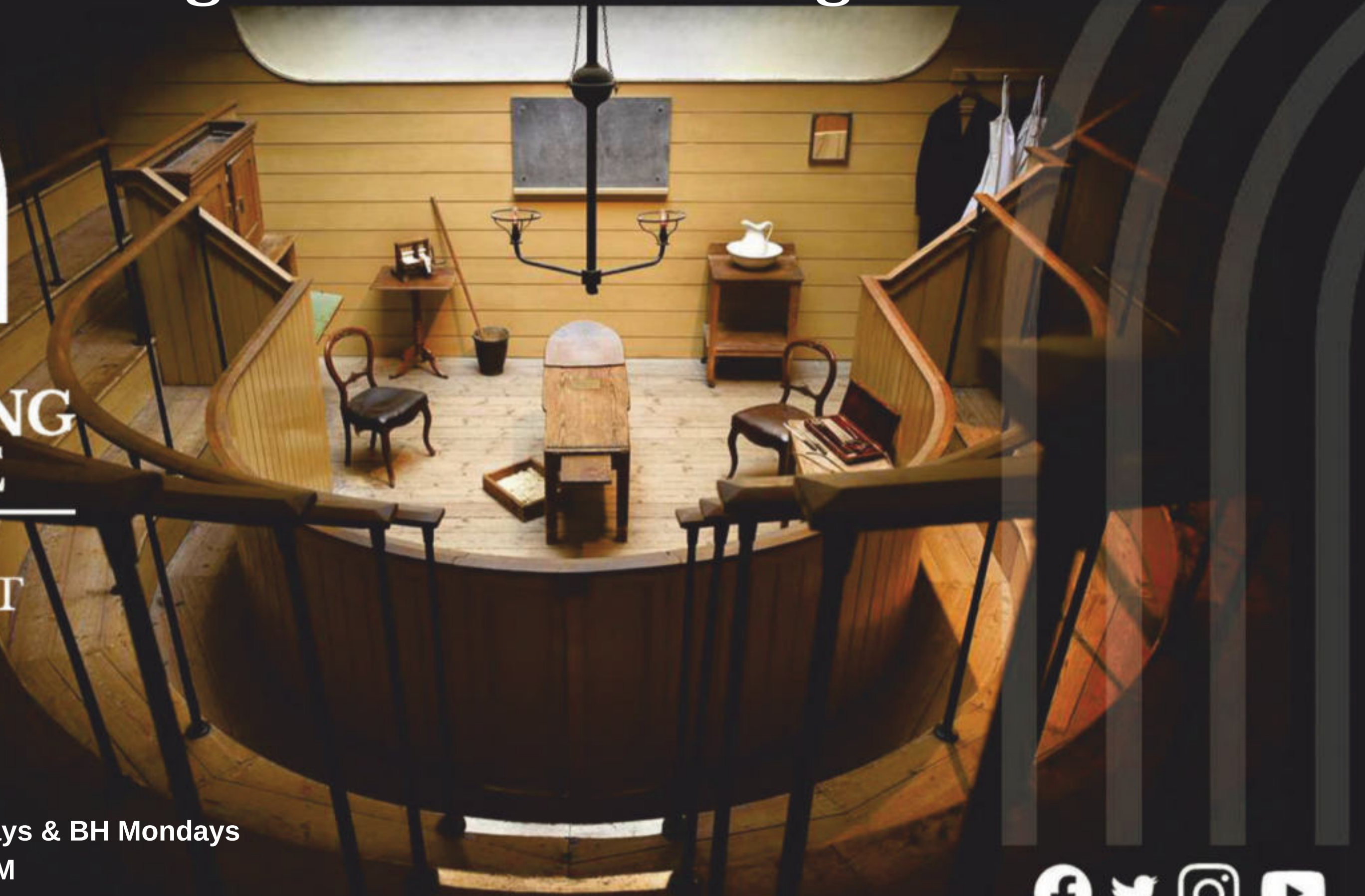

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WHAT IF... (WE BANNED FISHING?)

WORDS: **HAYLEY BENNETT**
ILLUSTRATION: **JASON RAISH**

FISHING DAMAGES ENTIRE ECOSYSTEMS AND POLLUTES OUR OCEANS. SO WOULD WE BE BETTER OFF WITHOUT IT?

On average, we each eat more than 20 kilograms of fish per year. Worldwide, between 1961 and 2016, fish consumption increased faster than meat consumption, and grew twice as fast as the human population.

All of these fishy dinners have depleted marine fish stocks to a point where a third of global fish stocks are now classed as 'overfished', meaning that if we continue fishing at the same levels, these populations will decline. Most of the rest are being exploited at the maximum levels that can be sustained without long-term decline. Fishing also has negative impacts on non-food species in the ecosystem, and pollutes the waters with fishing waste. Temporary fishing bans may help to alleviate some of the worst impacts, but what would happen if we banned fishing altogether?

BBC TWO

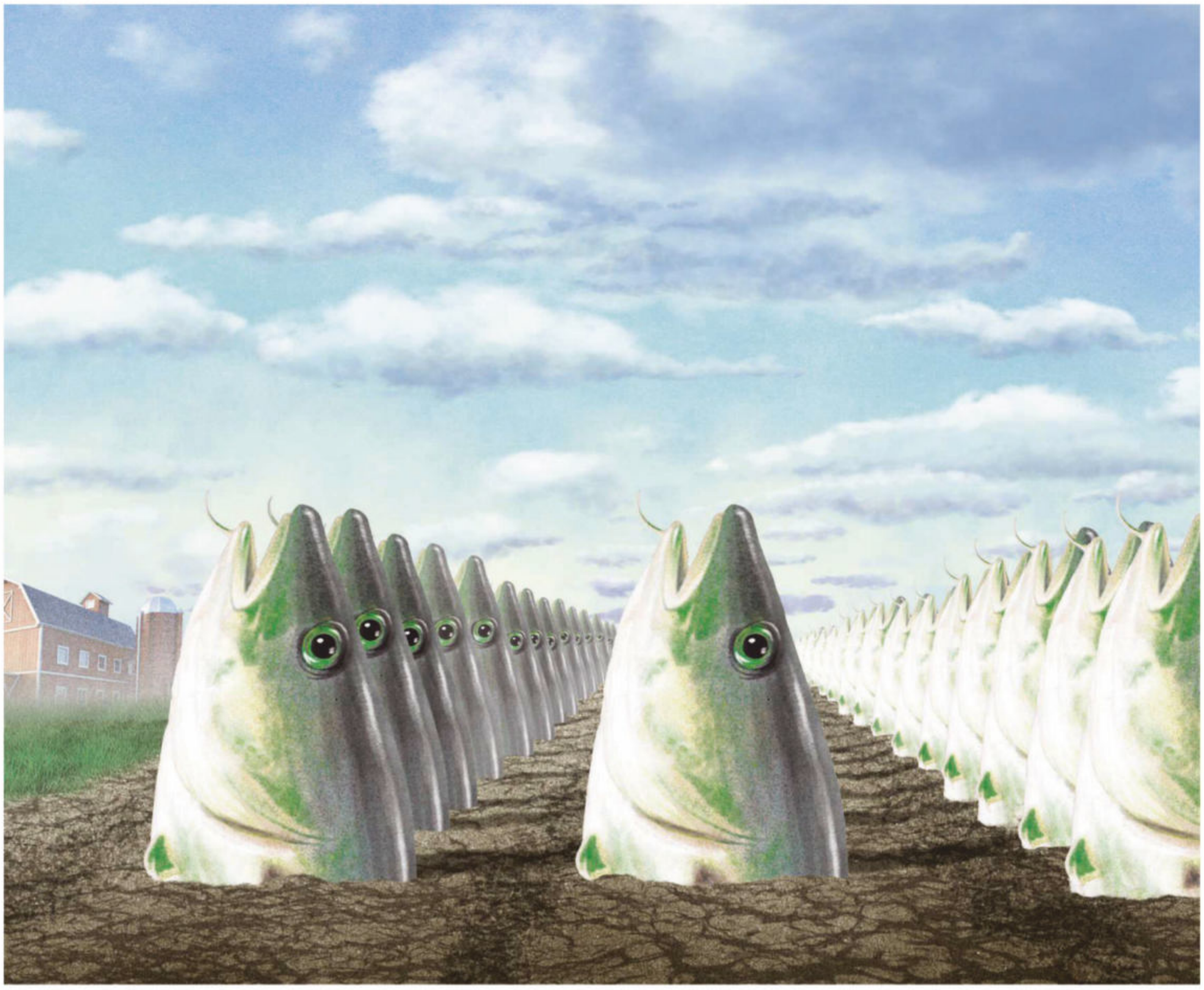
Watch *Cornwall: This Fishing Life*, a new series from the Open University and the BBC. Available now on iPlayer.

1

Millions would struggle to eat and earn enough

Around the world, 40 million people earn their living directly from catching wild fish, while another 19 million are employed in aquaculture – fish-farming or growing seafood in controlled conditions such as sea pens and cages, lochs and ponds. But these figures may hide the true extent of the planet's dependency on fishing. Along coasts, estuaries and coral reefs, millions of small-time fishers make a meagre wage from fishing, or catch fish just to put food in their families' mouths. Some fishers don't make the stats, and neither do their catches. "A lot of the small-scale catches are distributed in informal markets, where they're not recorded," says marine ecologist Dr Steven Purcell at Southern Cross University in Coffs Harbour, Australia. His own studies suggest that 71 per cent of those fishing for *Trochus* sea snails in the Samoan islands eat them themselves or give them away to friends and neighbours. Seafood is a major source of protein across Southeast Asia and islands in the Indian and Pacific Oceans. So while in Europe or the US we could eat more meat or soy products to make up for lost protein, a fishing ban could lead to food scarcity in communities with little land-based farming.

We can also envisage a black market developing for fish, as there currently is for beluga caviar in the US, where it's banned. Eggs from the endangered beluga sturgeon are thought to be flown in privately to top Manhattan chefs. In the case of a total fishing ban, think less about caviar, more about ordering canned tuna from dodgy websites.



2

Seafood farms could step up to meet demand

Aquaculture already produces nearly half of the seafood we consume (or more, if you include seaweed), and we'll have to increase that if we are to avoid decimating wild fish stocks. Under a fishing ban, aquaculture could be our only source of seafood, meaning that, initially, we'd be eating a lot of Atlantic salmon – by far the most farmed fish across Europe. "[Wild] fisheries allow you a diversity of products that aquaculture would probably take many years to get to," says Dr Sofia Franco at the Scottish Association for Marine Science. But she hopes to see a wider range of farmed seafood on the menu in future, as expertise in different species and farming systems develops. Until now, production has been largely in farms open to the sea, rivers, or lochs. Newer, land-based systems, such as tanks with recirculating water, could reduce pollution and damage to aquatic environments compared to the older systems.

But could you supply all the world's fish suppers without using a drop of actual seawater? Dr Rebecca Gentry, a marine scientist at Florida State University, suggests we wouldn't need to. Theoretically, aquaculture in the sea could produce the equivalent of the world's fishing catch in less than 1 per cent of the ocean surface, her 2017 paper shows. "It's an interesting thought experiment," she says. "If we close all wild fisheries, look at this huge amount of ocean area that we're no longer having an impact on." She doesn't want to paint "too sunny a picture" of aquaculture, though, noting that any large-scale food production fundamentally changes the environment.

3 Stocks would recover, but not all of them

Temporary bans on fishing of certain species are already used worldwide to maintain fish stocks and protect the environment. Some last a few weeks or months annually. These seasonal bans are designed to protect fish during their breeding seasons, for example, or to protect the sea bottom from damage, as with shrimp trawling bans. Others last most of the year, or longer, as in the current moratorium on fishing in the Arctic, which could last 16 years. A total global fishing ban would increase stocks, while helping to rebalance upset ecosystems. Eating less lobster thermidor, for example, would help keep seaweed forests in good health, as the crustaceans prey on sea urchins that destroy kelp – a type of seaweed.

However, there are no guarantees of a full recovery in our oceans. According to Purcell, some species are already so badly affected by overfishing that they might never recover. In Papua New Guinea, the edible sea cucumbers that he studies – popular in Asian cookery – have been so voraciously harvested that their populations are down to one-hundredth of their pre-fishing levels. “Once they get down to less than one animal per hectare, it’s very hard for the mates to find each other, particularly for these species that aren’t moving very fast,” Purcell says. “They have to crawl around on the seafloor to find each other.” Meanwhile, north of Australia, some shellfish populations exploited by Indonesian fishers have declined to the point where so few are now reproducing that rebuilding their populations looks impossible.

4 The oceans would be cleaner

Recent years have seen single-use plastics demonised as the public has woken up to the effects of marine plastics. But few people realise the contribution that fishing makes. Lost fishing gear accounts for about 10 per cent of all marine litter and, according to a 2018 study, 86 per cent of the big pieces of plastic floating in the ‘Great Pacific Garbage Patch’. Without fishing, we’d also wipe out pollution and emissions from fishing boats (one 2014 study claimed that lobsters were the most fuel-intensive species, with some boats using 20,000 litres of fuel to catch a single tonne). However, aquaculture could bring other sources of pollution, such as feed and chemical products that are used to control disease. These pollutants enter the sea where fish are farmed in pens and cages. Franco says that aquaculture is, at least in some sectors, less polluting than it was. “Consider salmon farming in the UK – antibiotics have not been routinely used in years,” she says. “But regulations and conditions can be very different in different sectors and countries.” Nevertheless, aquaculture globally will have to become more sustainable if the farmers want to access the most valuable markets, as these demand higher standards.

A further concern is that pushing seafood production onshore into high-tech systems like recirculating tanks would take space from other food production industries. One space-saving solution could be an integrated, ‘multitrophic’ system, growing fish, bivalves like mussels, and seaweed altogether. Gentry reckons that anything involving seaweed is “fabulous”, as the plants extract pollutants from the water, helping to purify it.

5

Corals would get some respite

Fishing affects the whole ecosystem and, as such, reef fishing has had a huge impact on some of the most vulnerable marine ecosystems – corals. Banning fishing could not only relieve pressure on some of the 4,000 fish species that live around coral reefs, but also on the corals themselves.

It's not always immediately obvious how fishing affects the corals, but Purcell gives one example. Crown-of-thorns starfish are a scourge on reefs because they eat the living part of the corals – the polyps. If the starfish populations are not controlled by predators, too many polyps will fall prey to these spiky creatures. But the starfish's predators are emperor fish, which are caught for food, and triton snails, which are prized for their shells. "I don't think [fishing] is the only reason we're getting outbreaks of crown-of-thorns starfish," says Purcell. "But it's one of the problems, and it contributes to taking out the [starfish's] predators."

Meanwhile, climate change and increasing sea temperatures continue to stress and bleach corals, which can then become overgrown with algae. A fishing ban could help bolster populations of the fish needed to clean away this suffocating slime. Cleaning up coral reefs could also ensure that they remain tourism destinations for years to come, supplying local communities with precious income, especially if fishing wasn't an option. **SF**

by HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a science writer and (sustainably sourced) fish finger sandwich fan, based in Bristol, UK.

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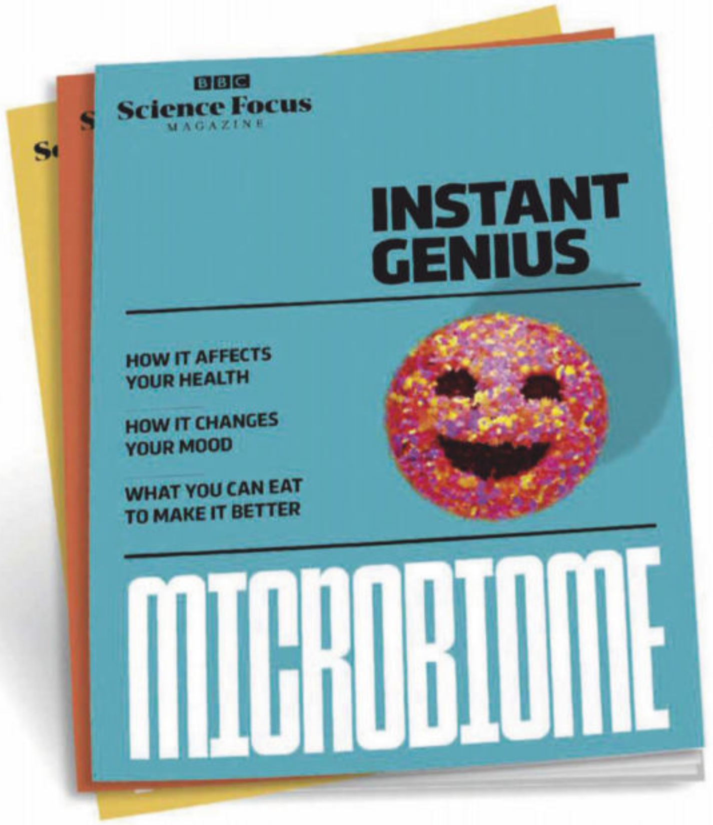
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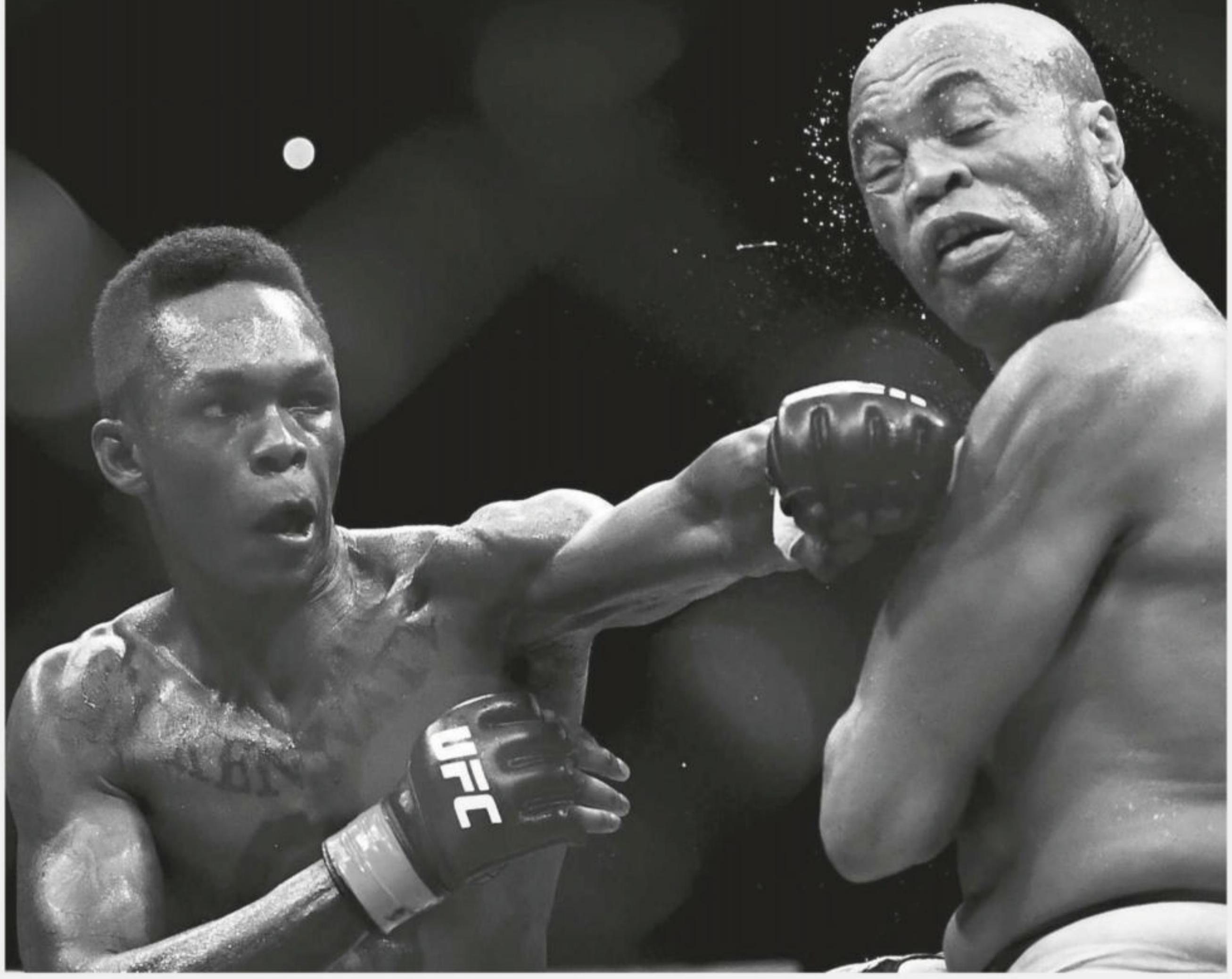
SEB JOWETT, EPSOM

WHY DO WE ENJOY WATCHING OTHER PEOPLE FIGHT?

Since time immemorial, humans have competed against each other in activities that have real-life survival value, be that throwing a javelin, jousting, boxing or wrestling. This makes sense from an evolutionary point of view, as those who honed these skills were more likely to survive when faced with a real-world conflict. Watching combat sports such as boxing and wrestling is an extension of that habit, with all the thrill but none of the personal danger.

Of course, some of us find such thrills more appealing than others. A survey at Indiana University Bloomington, US, of hundreds of undergrads found that those with more risk-seeking personalities, who said they enjoyed feelings of fear, derived more pleasure from watching mixed martial arts (MMA) and chose to watch the sport more often. However, it's not necessarily the violence that many combat fans are attracted to. A survey of attendees at an amateur MMA event found that the drama of the occasion was a stronger pull. In many sports, the most the competitors have to lose is their pride, whereas fighters and pugilists are quite literally putting their bodies, and sometimes even their lives, on the line. From a spectator's perspective, the greater the stakes, the more exciting the drama. ***CJ***



GETTY IMAGES

SANDRA MEYER, EXETER

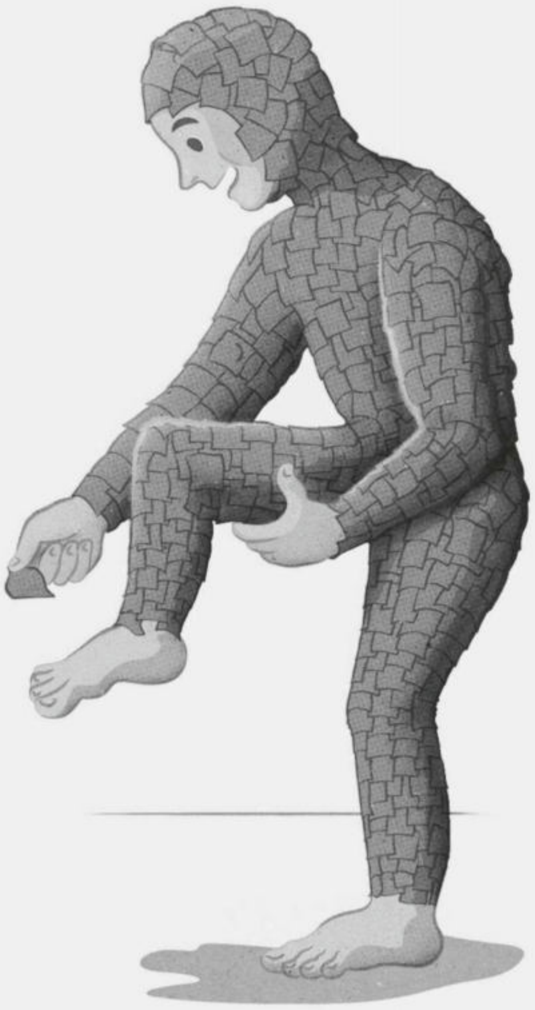
HOW DID THE HEART BECOME SYNONYMOUS WITH LOVE?

The Ancient Egyptians noticed that the veins and arteries, as well as many nerves, radiate outwards from the heart, and concluded that it was central to both reason and emotion. Later, the Ancient Greeks moved responsibility for rational thought to the brain, but passion has always remained associated with the heart. The adrenaline surge from any strong emotion has a powerful effect on our heart rate, so naturally we feel the pangs of love and attraction in our chest first. ***LV***

MARTIN COX, NEW MILTON

IF A NON-SMOKER WAS TO WEAR NICOTINE PATCHES, WOULD THEY BECOME ADDICTED TO NICOTINE?

It's possible, but patches are likely to be less addictive than cigarettes. You inhale about 1mg of nicotine from each cigarette. Daily nicotine patch doses vary from 5mg to 25mg, so a nicotine patch can give the same amount of nicotine as a pack of cigarettes. However, cigarette smoke is absorbed through the lungs much faster than the steady dose delivered through a skin patch. The sudden spike of nicotine from smoking, followed by the corresponding low, is part of what creates the addiction in the brain. Patches also don't come with the social rituals associated with cigarette smoking. A small number of people have reported feelings of dependency from nicotine replacement mouth sprays and gum, however, so using any nicotine replacement products, except as a way to quit smoking, isn't recommended. ***LV***



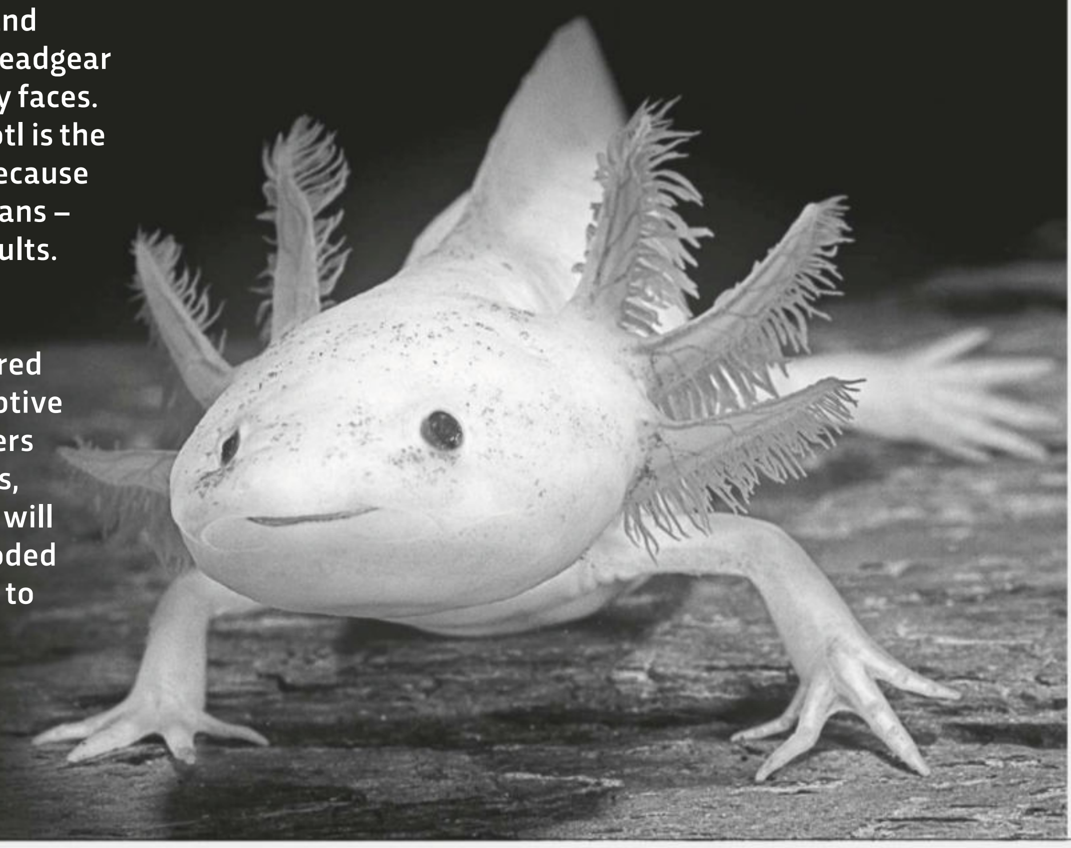
NATURE'S WEIRDEST CREATURES...

THE AXOLOTL

With their bald heads, button eyes and gummy smiles, axolotls are undeniably cute… and weird. Aside from their chunky bodies and comically short limbs, they sport some seriously outrageous headgear in the shape of six feathery gills that frame their adorable baby faces.

Their unusual appearance harks from the fact that the axolotl is the Peter Pan of the animal kingdom. They never really grow up because they are 'neotenous', which means that – unlike most amphibians – they never metamorphose into lung-breathing, land-living adults. Instead, they retain juvenile features such as gills, tails and a preference for living in water.

The axolotl – a species of salamander – is critically endangered and native only to Mexico City's Lake Xochimilco. However, captive populations are thriving in labs around the world, as researchers study the axolotl's extraordinary ability to regrow whole limbs, bits of brain, and segments of spinal cord when injured. Genes will be at the heart of this superpower, and, in 2018, scientists decoded the axolotl's genome, in the hope that we may one day be able to harness this ability for ourselves. They found that the genome contains 32 billion DNA base pairs, making it 10 times larger than the human genome, and the biggest animal genome deciphered to date. Why that is, no one knows! *HP*



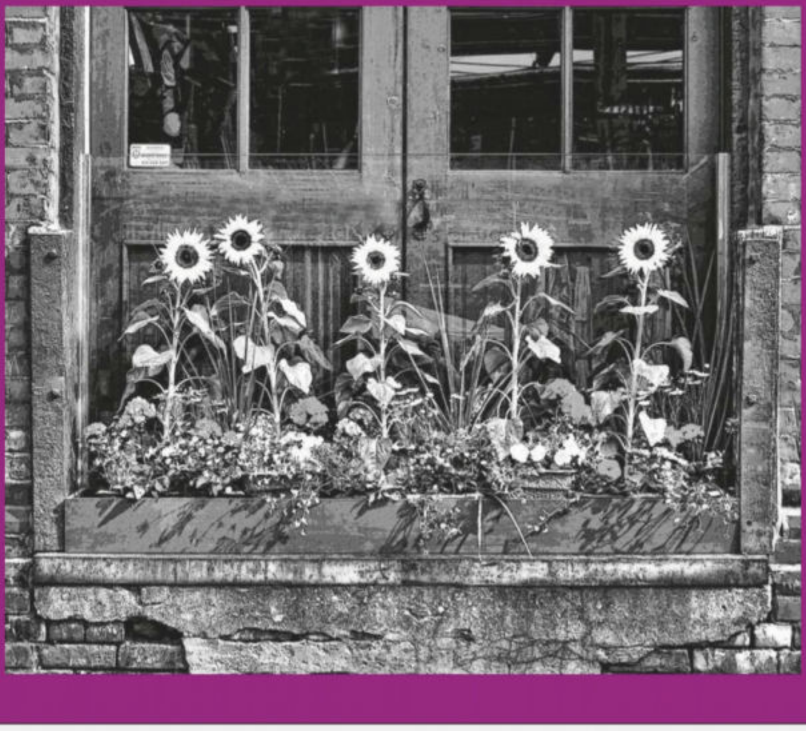
CROWDSCIENCE

We've teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at **www.bbcworldservice.com/crowdscience**

CAN WE SAVE THE INSECTS?

ARE INSECTS DYING OUT?

It appears so. A report published in the journal *Biological Conservation* last year warned that more than 40 per cent of the world's insect species are threatened with extinction over the next few decades. Moths and butterflies, dung beetles, ants and bees were highlighted as being especially vulnerable. Entomologists have so far named around one million insect species, but there are an estimated five million insect species on the planet, and many of these could become extinct before being recorded by science. Habitat loss, pesticides, disease, and climate change are all thought to be to blame for insects' demise.



WHY SHOULD WE BE WORRIED?

For starters, they play a crucial role in the food chain. Insects are eaten by most birds, which collectively consume as many as 500 million tonnes of creepy-crawlies every year.

Insects also pollinate our flowers and crops, providing unpaid labour that's estimated to be worth between $235bn (£180bn approx) and $577bn (£443bn approx). Bees play the major role, but other insects make up 40 per cent of visits to crop flowers. Flies, for example, are crucial pollinators of the cocoa tree. Insects are also useful at the other end of the food chain. They break down huge quantities of animal poo and dead animals, recycling nutrients back into the ground.

WHAT CAN WE DO ABOUT IT

Farmers can think more about the insects that pollinate their crops. For example, the cocoa tree – the seeds of which give us chocolate – is pollinated by around 15 species of midge (tiny flies). In order to increase cocoa yields, farmers often remove other trees from the area, but this removes the shade that midges prefer, and the decomposing leaf litter that their larvae need to grow. On an individual level, we can all protect our own little bit of greenery. Even if you have a small garden or a window box, encourage insects by planting native plants and wildflowers, and remember: nature likes things messy and undisturbed. If you need an excuse not to mow the lawn, this is one!

Marnie Chesterton is the presenter of *Can I save the insects?* – an episode of CrowdScience that can be streamed at **bbcworldservice.com/crowdscience**

GETTY IMAGES X4 ILLUSTRATION: DAN BRIGHT

LULU PARKER, LONDON

WHY DON'T PLANTS GET SUNBURN?

Around 700 million years ago, plants began to appear on land. One of the key adaptations needed for this transition was some way to protect against the Sun's ultraviolet (UV) rays; plants in the sea had hitherto been shielded by the seawater. Scientists have known since 2011 that plant cells have a protein called UVR8 that can detect shorter wavelength UVB rays, which is the type of UV radiation most responsible for sunburn. This protein signals the cells to begin producing compounds that block further UV damage and repair DNA damage. In 2014, researchers at Purdue University in the US identified one of these protective compounds as 'sinapoyl malate' and found that this molecule harnesses quantum mechanical effects in order to absorb UVB rays. The ability to produce this natural sunscreen seems to be common to all land plants and algae, which suggests it is an ancient adaptation.

Plants aren't invulnerable to the Sun, however. Prolonged exposure to the UVB in strong sunlight causes cell damage to the leaves and bark of many plants. This is worse when plants are dehydrated, because this limits their ability to move sunscreen chemicals to the worst-affected sites. Ironically, there is a widely-held belief among gardeners that watering plants in the midday sunshine can cause sunburn, because droplets of water supposedly act as tiny lenses to focus the sunlight onto the leaf surface. However, this myth was debunked in 2011 by researchers at Eötvös University in Budapest, Hungary. They used computer modelling and direct experiment to show that the refractive index of water isn't strong enough to focus sunlight from a water droplet onto the surface of a leaf. ***LV***

ERIC WILLIAMS, LANCASHIRE

WHY DOES BLOWING HARD ON OUR HANDS COOL THEM, BUT JUST BREATHING ON THEM WARM THEM?

This is essentially due to a difference in the speed of the airflow in each case. When we breathe out slowly on our hands, the warmth and moisture from our mouths has time to transfer to our hands, warming them up. But pursing our lips speeds up the airflow, and as this passes over our hands, it blasts away any air that's been warmed by contact with our hands, cooling them. In addition, the fast-moving column of air draws in, or 'entrains', the air around it. This tends to be cooler than our breath, so it boosts the cooling effect. *RM*

CHRIS MCMULLON, BARNHAM, WEST SUSSEX

ARE THERE ANY ANIMALS THAT CAN SEE WI-FI OR BLUETOOTH SIGNALS?

Wi-Fi and Bluetooth are radio signals with a wavelength of 6cm to 12.5cm. This is about 100,000 times longer than the wavelengths of visible light that humans can see. Many animals, including vampire bats and certain fish and snake species, are able to sense infrared radiation, but this only goes up to wavelengths of 1mm. Longer wavelengths carry much less energy and can't be detected without some kind of resonator to amplify the signal. In 2009, the French virologist Luc Montagnier claimed that bacterial DNA can emit radio waves, but his results were met with widespread criticism from the scientific community, and have not been replicated. So to date, we don't know of any organisms that can detect or communicate with radio frequency signals. *LV*

GETTY IMAGES X2 ILLUSTRATIONS: DAN BRIGHT

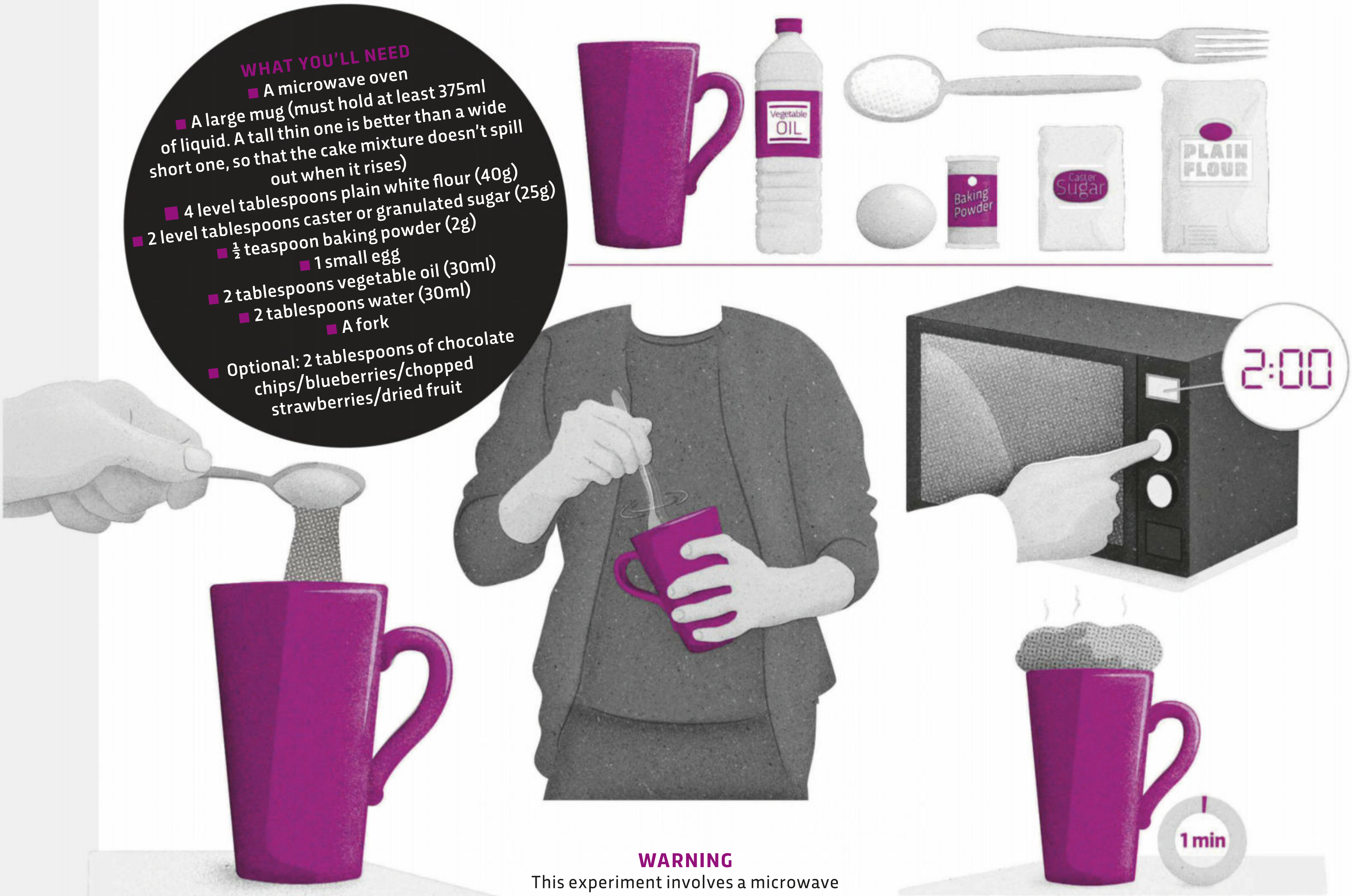
DIY SCIENCE

MICROWAVE CUPCAKE

We'd love to see pictures of your cakes. Send them to us on Facebook or Twitter (**@sciencefocus**) and we'll share our favourites!

WHAT YOU'LL NEED

- A microwave oven
- A large mug (must hold at least 375ml of liquid. A tall thin one is better than a wide short one, so that the cake mixture doesn't spill out when it rises)
- 4 level tablespoons plain white flour (40g)
- 2 level tablespoons caster or granulated sugar (25g)
- ½ teaspoon baking powder (2g)
- 1 small egg
- 2 tablespoons vegetable oil (30ml)
- 2 tablespoons water (30ml)
- A fork
- Optional: 2 tablespoons of chocolate chips/blueberries/chopped strawberries/dried fruit



WARNING
This experiment involves a microwave and results in an extremely hot cake, so make sure young children are supervised by an adult.

WHAT TO DO

1. Pour the flour, sugar and baking powder into the mug and mix well.

2. Add the whole egg, oil, and water and beat with the fork until you have a smooth batter.

3. Add chocolate chips, berries or dried fruit as desired and mix well into batter.

4. Place mug in microwave and cook on full power for two minutes.

5. Remove mug from microwave and allow to cool for a minute or so.

6. Eat cake!

WHAT'S HAPPENING

Your cake is the result of several chemical reactions and physical changes driven by energy provided by the microwave oven.

The main body of the cake comes from the flour and water. Mixing these two ingredients together causes some of the proteins in the flour to form an elastic network of proteins called gluten. Heat causes the rubbery gluten to coagulate into a strong structure.

When the cake batter is heated, an alkali (sodium bicarbonate) and an acid (usually cream of tartar) in the baking powder react to produce bubbles of carbon dioxide, which cause the cake to rise. Meanwhile, the egg in the batter coats the bubbles and hardens around them, resulting in the holes in the cake that give it a spongy texture. The oil coats all of the ingredients and prevents the cake from drying out.

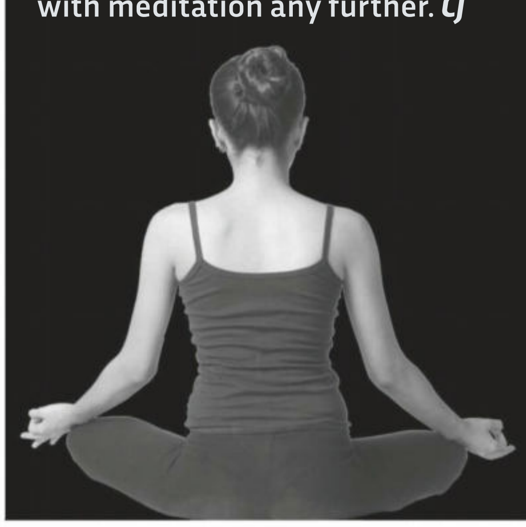
Of course, a cake would be nothing without its sweetness. The sugar provides this, and any chocolate or fruit you add creates an extra dimension of flavour and texture. ***AS***

DEAR DOCTOR...

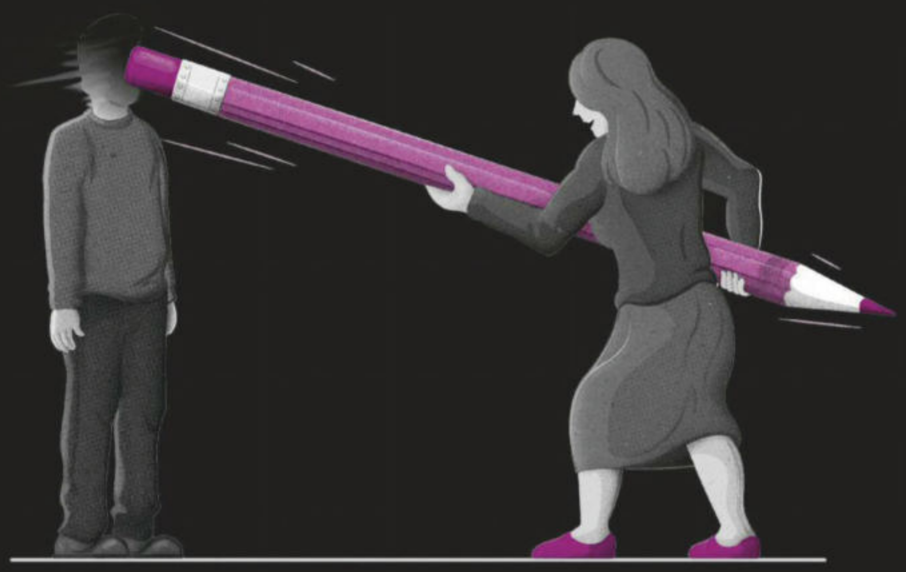
DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

MEDITATION LEAVES ME FEELING MORE STRESSED. WHAT AM I DOING WRONG?

While there's plenty of evidence for the positive effects of meditation, it's not completely risk-free. Its contemplation and focused awareness can bring uncomfortable thoughts and feelings to the surface. A 2017 survey by psychologists in Spain and Brazil found that around 25 per cent of regular meditators have 'unwanted experiences', including panic attacks, emotional feelings and derealisation (losing contact with reality). So you might not be doing anything 'wrong'. In fact, in many meditative traditions, confronting the challenges – and learning how to accept and work with them – is seen as an important part of the exercise. However, some people are more vulnerable than others. For example, people with pre-existing severe anxiety can experience 'relaxation-induced anxiety' when they meditate. This might be because they fear a shift back to their baseline anxiety level after being in a more relaxed state. If you're struggling with this or any other mental health issue, you should seek professional support before experimenting with meditation any further. ***CJ***



MY OTHER HALF'S PENCIL ERASER COLLECTION IS TAKING OVER THE HOUSE. PLEASE HELP ME TO UNDERSTAND HIM.



Collecting unusual objects is more widespread than you might think, and there can be various psychological factors at play. For starters, we have an evolved tendency to accumulate resources, and whereas this used to be food or tools for survival or status, today it manifests in more idiosyncratic ways – such as erasers. Your partner's collection might be akin to an adult 'comfort blanket' – while all around is in constant change, the collector retains complete control over their growing collection. A collection can build up over years or even decades, and this seeming permanence can also provide consolation against existential anxieties. In fact, many collectors will make careful plans for what happens to their collection after they die. The focus of your partner's collection might strike you as strange, but erasers make an appealing item. They're small, cheap, come in infinite forms, are multisensory (I'll bet he has some scented erasers) and can be imbued with memories from the collector's childhood, for instance. ***CJ***

I LOVE EATING GARLIC BREAD FOR LUNCH. WHAT'S THE QUICKEST WAY TO FRESHEN MY STINKY BREATH FOR AFTERNOON MEETINGS?

As you digest your lunch, the smelly, sulphur-containing compounds ('sulphides') in the garlic are absorbed into your bloodstream, and will come out via the exhaled breath from your lungs, and even from pores in your skin. Brushing your teeth (and your tongue), and swirling with mouthwash, will help to temporarily mask the smell. Even better, though, a 2016 study at Ohio State University found that lettuce, apples and mint leaves contain enzymes and chemicals called 'phenolic compounds' that break down garlic's sulphides before they reach the blood. So chomp on apples or mint leaves after lunch! ***LV***

STEVE WELCH, VIA EMAIL

WHAT WOULD A SHOOTING STAR LOOK LIKE IF IT WAS COMING STRAIGHT TOWARDS YOU?

A shooting star, or 'meteor', is caused by a tiny piece of rock or dust burning up in the Earth's atmosphere. If one was coming straight at you, it would appear as a brief flash of light at a single point in the sky – rather than the usual streak of light we associate with shooting stars. This brief flash would be difficult to spot with the unaided eye, but they can be seen in long-exposure photographs of meteor showers. ***AGu***

TERRY PRIEST, WEST SUSSEX

WHY DOESN'T HONEY GO OFF?

Honey can last for thousands of years in sealed pots – it's even been discovered in Ancient Egyptian tombs. The secret to its long life lies in the bees' honey-making process. Forager bees collect sugary nectar from flowers and transport it back to the hive. Here, the bees transfer the nectar to other worker bees, which repeatedly drink and regurgitate the liquid, reducing its water content. During this process, an enzyme in the bees' stomachs breaks down the nectar's glucose into gluconic acid – which helps to make honey acidic (pH of around 4) – and hydrogen peroxide. Once the nectar is deposited in the honeycomb, the bees fan it furiously with their wings to speed up the water's evaporation. The honey's low water content and high acidity are the two main reasons it doesn't spoil – the bacteria that cause food to go off can't thrive in these conditions. The hydrogen peroxide also has antibacterial properties. So the honey stays fresh for the bees during the cold winter months – and for much longer inside our jars. ***ED***

GETTY IMAGES X4, SCIENCE PHOTO LIBRARY ILLUSTRATIONS: DAN BRIGHT

SHARON HACKETT, WEST SUSSEX

WHY DO I FEEL SICK WHEN I'M HUNGRY?

When you're hungry, the hydrochloric acid in your empty stomach can slosh about and hit the lower oesophageal sphincter (the valve that holds the top of your stomach closed). This is also what happens when you throw up, and it triggers similar feelings of nausea. Hunger can also stimulate the 'area postrema' structure in your brainstem, which detects bacterial toxins in the blood to make you throw up in response to food poisoning. For some reason, very low blood sugar can sometimes trigger a false alarm. ***LV***

13

The amount, in metres, that the Sun vibrates back and forth every second. This is because of Jupiter's strong gravity pulling on the star.

HIDDEN FIGURES

ERNST STUECKELBERG
UNSUNG GENIUS OF MODERN PHYSICS

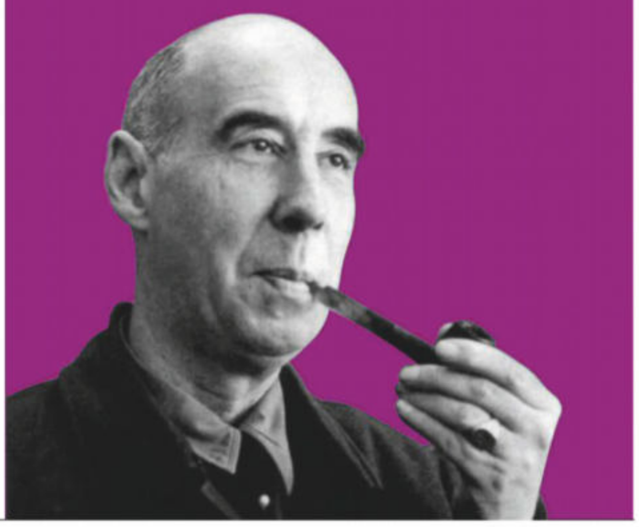
At the end of a lecture in the 1960s, the celebrated physicist Richard Feynman spotted a man quietly leaving the auditorium. "He did the work and walks alone towards the sunset," Feynman declared. "And here I am, covered in all the glory which rightfully should be his."

While few have heard of the Swiss physicist Ernst Stueckelberg, his insights into subatomic physics were so profound that he should have shared at least three Nobel Prizes.

Born in 1905, by his early 30s Stueckelberg had come up with the revolutionary – and now proven – idea that atomic nuclei are held together by a force carried by subatomic particles. Dismissed as ridiculous, Stueckelberg dropped the idea – which was then rediscovered by a Japanese theorist, winning him a Nobel.

Stueckelberg went on to solve technical problems with the theory of quantum electrodynamics, which describes how light and matter interact. His complex ideas appeared in obscure journals and got overlooked – until Feynman and others came up with similar ideas, winning them the Nobel.

Undaunted, Stueckelberg devised a theory for how subatomic forces behave in particle accelerators. His prediction was confirmed a few years after his death in 1984 – by which time others had already won Nobels for similar work. Stueckelberg's brilliance but obscurity proves that in science, as in life, being first is not enough. You also need to get noticed. ***RM***

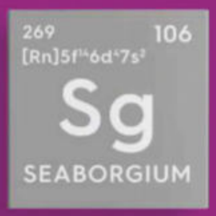


WHAT CONNECTS

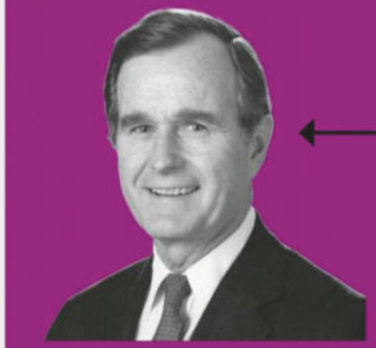
CARLSBERG BEER AND GEORGE BUSH SR?

1. The Carlsberg brewery sponsored the research of Danish physicist Niels Bohr, who won the Nobel Prize in Physics in 1922. To honour his achievements, in 1932 Carlsberg gave him a house with free beer on tap, piped directly from the brewery next door.

2. Bohr had an element of the periodic table named after him – bohrium (Bh). Bohr himself played no part in its discovery, though, and the element was named 35 years after his death.



3. The element to the left of bohrium in the periodic table is seaborgium (Sg). It was discovered by and named after American nuclear chemist Glenn Seaborg – the first time an element had been named after a living scientist.



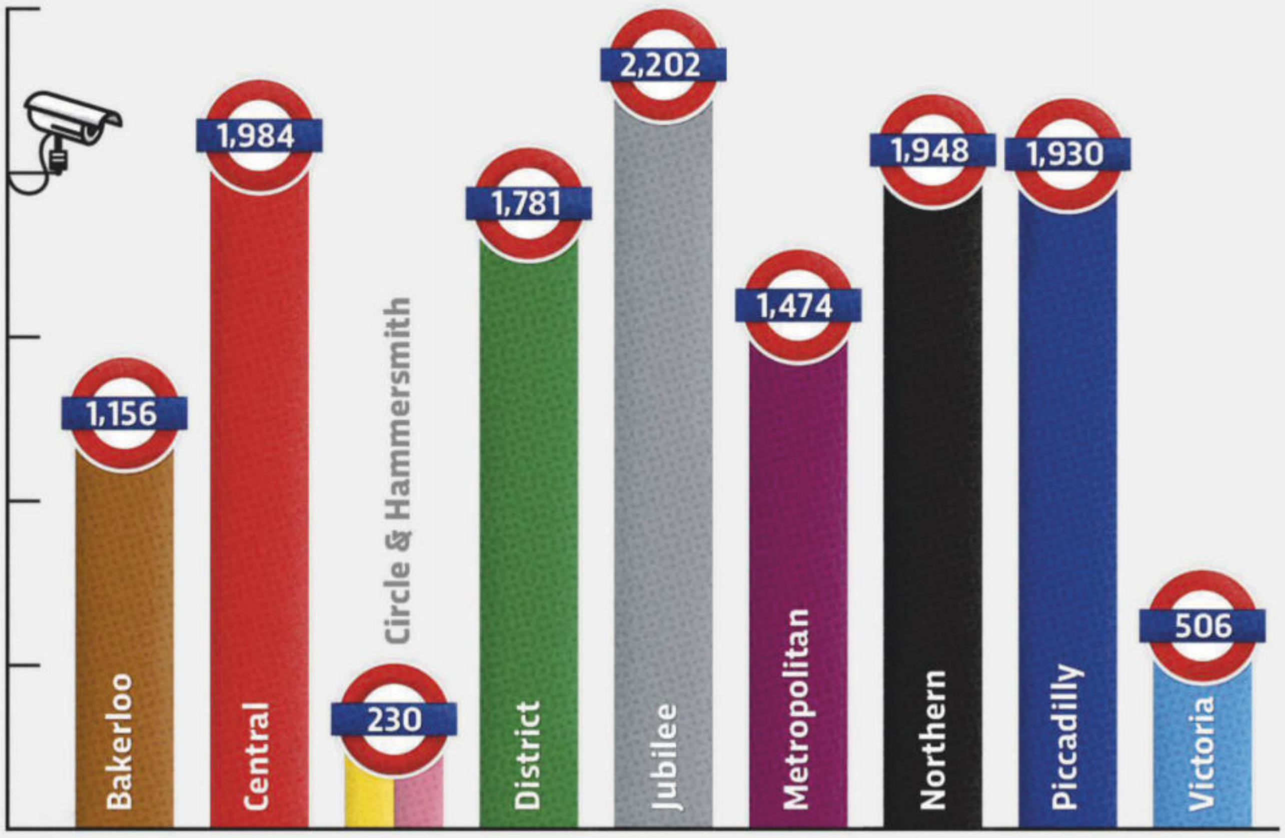
4. Seaborg won the Nobel Prize in Chemistry in 1951 for his part in the discovery of 10 elements, and served as a science adviser to 10 US presidents – from Franklin Roosevelt to George Bush Sr.

SCOTT ROGERS, SHEFFIELD

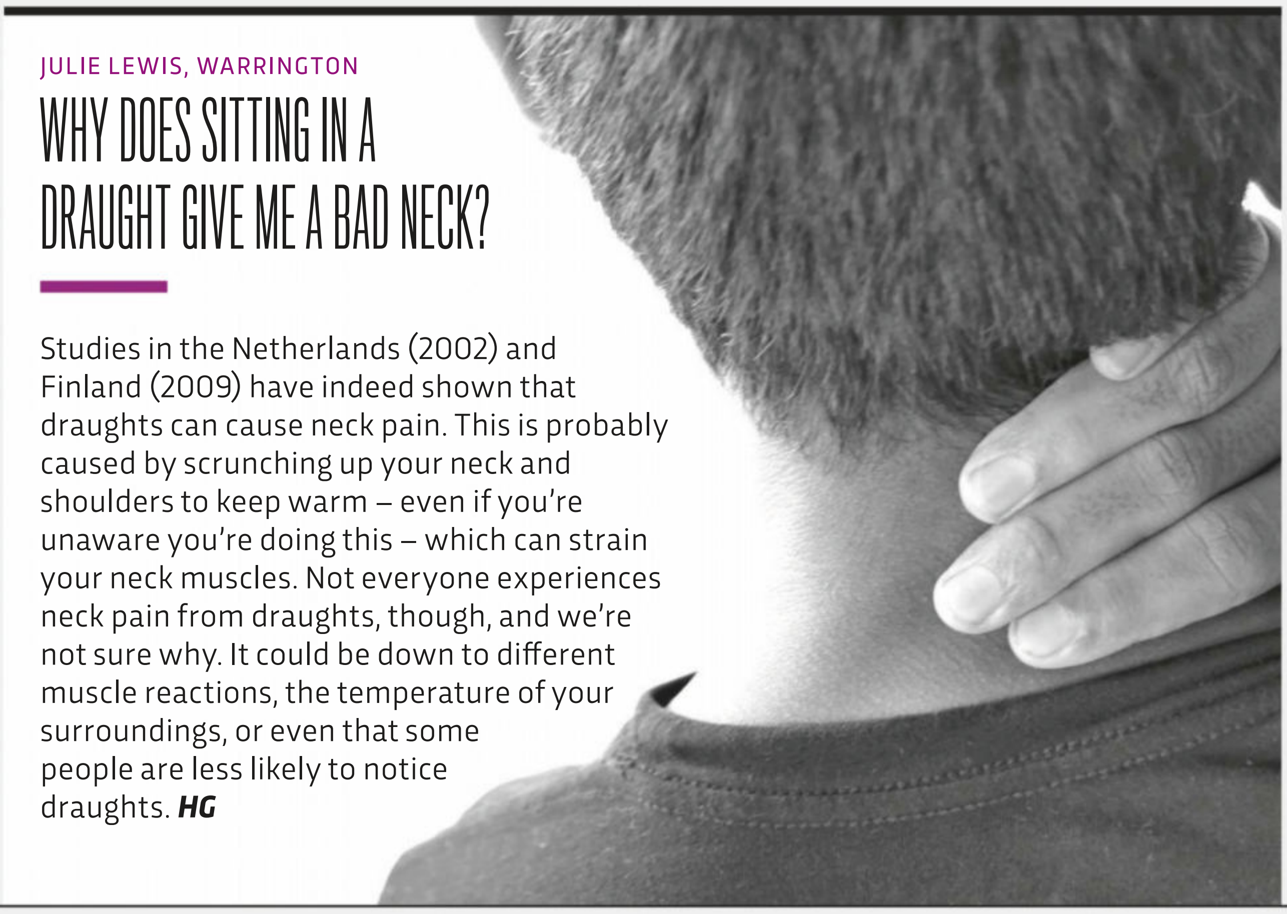
WHY ARE CCTV IMAGES STILL SO RUBBISH?

The number of CCTV cameras in the UK has been estimated at up to six million, most of which are installed in private homes and businesses. All CCTV cameras – whether the older, analogue type or the more modern, digital ones – have to make trade-offs between picture quality, storage and cost. There are around 13,000 cameras in London Underground stations alone, and the footage from these is kept for two weeks. Upgrading all of these to record at 4K quality instead of 1080p would require an extra 300 million gigabytes of storage, not to mention the cost of the cameras themselves. CCTV cameras also generally use wide-angle lenses to cover the broadest possible area. Digitally zooming in on a single person in the distance inevitably results in a blurrier image. Nevertheless, image quality is increasing all the time, and image processing software and machine learning algorithms can now recognise faces even from low-resolution video. ***LV***

CCTV CAMERAS ON THE LONDON UNDERGROUND



Data correct as of May 2019, Source: bit.ly/CCTV_tube



JULIE LEWIS, WARRINGTON

WHY DOES SITTING IN A DRAUGHT GIVE ME A BAD NECK?

Studies in the Netherlands (2002) and Finland (2009) have indeed shown that draughts can cause neck pain. This is probably caused by scrunching up your neck and shoulders to keep warm – even if you're unaware you're doing this – which can strain your neck muscles. Not everyone experiences neck pain from draughts, though, and we're not sure why. It could be down to different muscle reactions, the temperature of your surroundings, or even that some people are less likely to notice draughts. ***HG***

GETTY IMAGES X6, ALAMY X2 ILLUSTRATIONS: DAN BRIGHT

JASON WEBB, TENNESSEE

WHAT COLOUR IS SPACE?

If we add up all the light coming from galaxies (and the stars within them), and from all the clouds of gas and dust in the Universe, we'd end up with a colour very close to white, but actually a little bit 'beige'. Averaged over the whole sky, however, this beige colour is diluted and appears almost, but not quite, black. Given the immense size of the Universe, and the abundance of stars, it might be surprising that the sky isn't bright white. This is because the Universe has a finite age, and the light from the furthest stars hasn't had time to reach us yet. ***AGu***

COLIN ROWLEY, VIA EMAIL

ARE RAZORS WITH MORE BLADES REALLY BETTER?

With a multi-bladed razor, the leading blade lifts the hair slightly as it cuts it. Before the hair has a chance to retract, the next blade reaches it and cuts a little lower down. This results in a shave that is not just flush with the level of your skin, but actually slightly below it. Naturally this is subject to the law of diminishing returns, but a razor with more blades also distributes the pressure of the blade cartridge more evenly. There is some evidence that this keeps your skin flatter so that you get a more even shave and less chance of nicks and cuts. So it is worth going for a multi-bladed razor, but whether you're better off with three, five, or even seven blades is going to come down to what feels most comfortable for you. Almost all scientific research in shaving technology is sponsored by one of the razor manufacturers, so a truly objective figure for the optimum number of blades is hard to come by. ***LV***

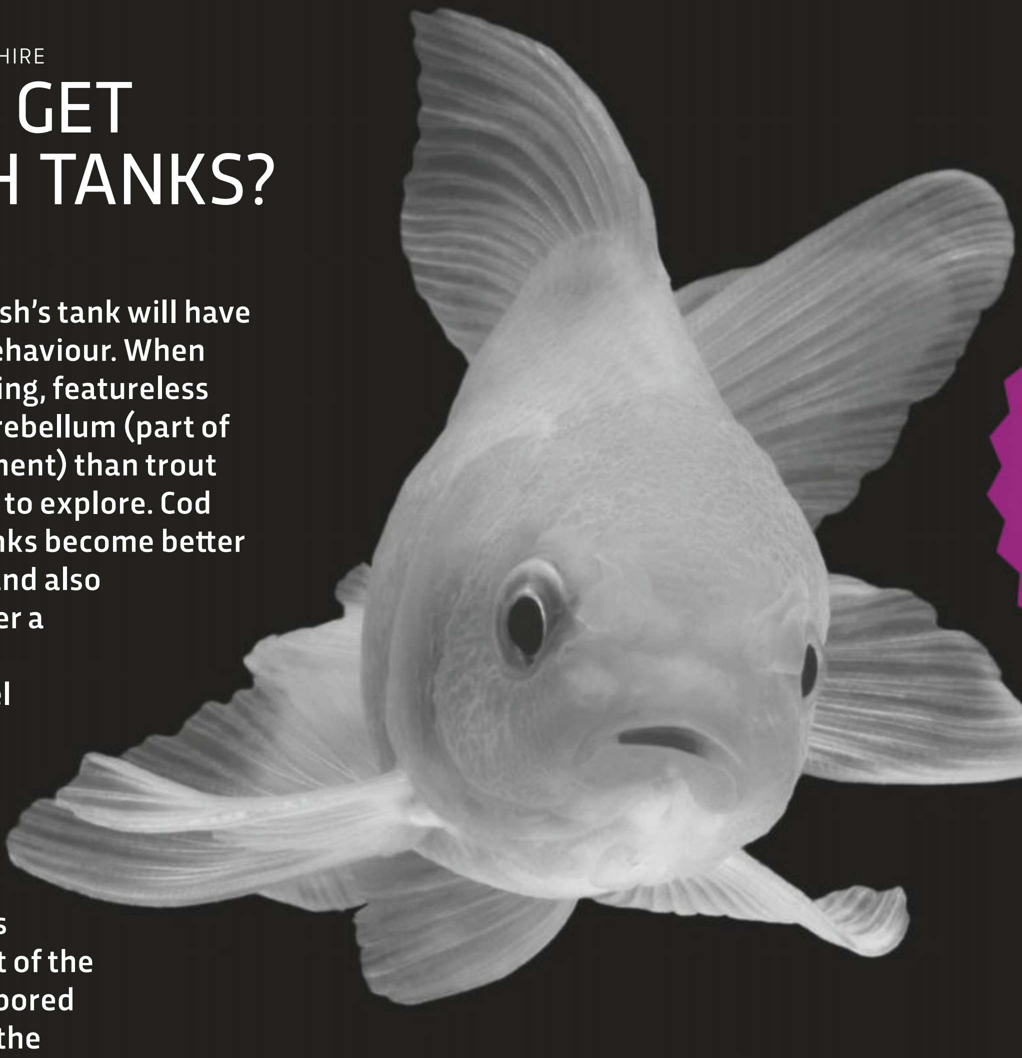
QUESTION OF THE MONTH

LUKAS HINDMARCH, NORTH STAFFORDSHIRE

DO FISH EVER GET BORED IN FISH TANKS?

We know that the nature of a fish's tank will have an influence on its brain and behaviour. When young trout are reared in a boring, featureless tank they develop a smaller cerebellum (part of the brain that regulates movement) than trout that are given rocks and plants to explore. Cod reared in similarly enriched tanks become better at learning how to catch prey, and also recover quicker from stress after a simulated predator attack.

But whether fish actually feel bored in a way we can relate to is harder to work out. Fish-keepers sometimes see their pets 'glass surfing' – swimming repeatedly up and down the glass of the tank. This could be the aquatic equivalent of the pacing of a captive tiger that's bored from a lack of stimulation. But the fish could also be stressed from an overcrowded or unfamiliar tank. *HS*



WINNER

Lukas wins a bundle of stunning books by Rachel Ignotofsky, worth £51.96. The books include: *Women In Science, Women In Sports, Women In Art* and *The Wondrous Workings Of Planet Earth*. Featuring beautiful illustrations and stacks of fascinating stories and facts, these books are an absolute treat to read.
hachettechildrens.co.uk

WOMEN IN SCIENCE
WOMEN IN ART
WOMEN IN SPORTS
PLANET EARTH

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH

It's in our genes
We talk racism, race and genetics with Dr Adam Rutherford p92

The cosmetic truth
Concerned about the ethics of makeup? Tune in to *Beauty Laid Bare* p94

Reading list
Check out our best selection of new reads this month p94

Books that made me
Neuropsychiatrist Prof Anthony David reveals his favourite books p95

1

MEET VINCENT VAN GOGH

London

This interactive and multisensory installation allows you to experience Van Gogh's artwork like never before. Reach out and touch the strokes of his paintbrush, climb a golden haystack from his *Wheat Fields* series, and sit at *The Potato Eaters'* table. There are 12 interactive stations in the experience, including the Kinect installation which allows you to paint with Van Gogh's colours using motions and gestures, while projections of his art let you walk beneath a starry sky. Tickets from £14.

Until 21 May

meetvincent.co.uk

2

WILDERLAND FILM FESTIVAL

Created by zoologist Dan O'Neill, *Wilderland* is the UK's first touring wildlife film festival. Last year's festival included independent films from around the world.

Various dates and locations

wilderlandfestival.com

3

EDITOR'S CHOICE

THIS THING OF DARKNESS

BBC Radio 4

This gripping seven-part radio drama was inspired by the real work and files of forensic psychotherapist Dr Gwen Adshead. In episode one, a 19-year-old is murdered, and Dr Alex Bridges must interview members of the mourning family.

Mondays from 24 February, 2:15pm

4

STAR COUNT 2020

Head outside after dark, enjoy the stars and take part in a citizen science project this month. Led by CPRE, Star Count 2020 will help map where the best (and worst) places are to see stars.

No equipment is needed, simply look for the constellation of Orion and its famous belt. Take a moment to let your eyes adjust to the darkness and then count all of the stars you can see inside the constellation, excluding the four corner stars, and share your number with CPRE via the website.

21-28 February, when the Moon is least bright

cpre.org.uk/starcount

FOR THE FAMILY

MEET VINCENT VAN GOGH, THOMAS S G FARNETTI, GARRY KNIGHT, IDIL SUKAN, BELINDA LAWLEY, GETTY IMAGES

5

PERMISSION TO PLAY WEEKEND

Wellcome Collection, London

Visit the Wellcome Collection on this weekend to explore and play. There will be free workshops, games and talks open to the whole family.

15–16 February

wellcomecollection.org

6

NI SCIENCE FESTIVAL

Various venues in Northern Ireland

The programme for the sixth annual NI Science Festival features 270 events and will focus on environment and sustainability. Presenters this year include Claudia Hammond, Jim Al-Khalili and Adam Rutherford. Booking recommended.

13–23 February

nisciencefestival.com

7

THE DARWIN DAY LECTURE 2020: EVOLUTION OR EXTINCTION – WILL HUMANITY SURVIVE THE 21ST CENTURY?

Troxy, London

This year, The Darwin Day Lecture and medal will be awarded to Chris Packham CBE, as someone who's made a significant contribution to science. See him in conversation with Prof Alice Roberts. Tickets cost £24.75

12 February, 7:30pm

humanism.org.uk

8

WOMEN OF THE WORLD FESTIVAL

Southbank Centre, London

For its 10th anniversary, the WOW Festival will host performances and talks by inspiring women such as Naomi Wolf, Scarlett Curtis and Sandi Toksvig. Catch author and activist Caroline Criado Perez talking about her award-winning book on data bias, *Invisible Women*, and hear why gender matters in the tech world at the Women Byte Back talk. Listen to former President of Ireland Mary Robinson discussing feminist solutions to climate change, and watch a panel hosted by Fertility Fest. Day passes cost £40 each.

6–8 March

southbankcentre.co.uk

STAND UP TO RACISM
No to Islamophobia and antisemitism

Profile

THESE GENES DON'T LIE

IN HIS NEW BOOK, *HOW TO ARGUE WITH A RACIST*, GENETICIST DR ADAM RUTHERFORD QUASHES THE 'PROOF' THAT PEOPLE USE TO JUSTIFY THEIR RACIST BELIEFS

WHY DID YOU WANT TO WRITE THIS BOOK?

Three angles of my career and life have collided in this book. The first is that I'm a geneticist, so I'm interested in human variation, the basis from which historical descriptions of race have come.

The second thing is that I spent my entire career at University College London (UCL), which is, in many ways, the home of human genetics. I was in the Galton Laboratory, which was named after Francis Galton. Galton was sort of the founding father of both human and statistical genetics, but also of eugenics and some pretty awful ideas.

The third thing is that I'm mixed race. My maternal lineage is Indian, via indenture – which is a form of slavery – to Guyana. It's not been a major part of my personal life, but now, at the point in the 21st Century where conversations about race and genetics and nationalism all appear to be on the rise, I think that there is a reasonable case to be made that there is a co-opting of contemporary population genetics.

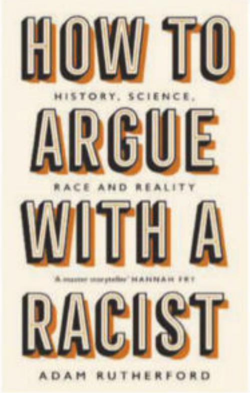
It was a sort of inevitable that this book was going to emerge from me, and I think needs to be published now more than ever.

> "The idea that there could be racial purity is just ahistorical, ascientific, it's an absolute nonsense"

WHAT DOES 'HUMAN VARIATION' REFER TO, AND HOW DOES THAT RELATE TO THE TERM 'RACE'?

This is a complex area, and historically, we've been pretty poor at trying to understand human variation. People throughout antiquity have been discussing how we are different all throughout the world, since humans have existed. There is no doubt that people look, behave and are different from each other.

Around the 15th Century, these conversations became formalised attempts to pin down the differences between the groups of people that Europeans were encountering as they conquered the other continents. Whereas historically, we could group people by superficial characteristics


HOW TO ARGUE WITH A RACIST
HISTORY, SCIENCE, RACE AND REALITY
ADAM RUTHERFORD

HOW TO ARGUE WITH A RACIST
ADAM RUTHERFORD
(£12.99, WEIDENFELD & NICOLSON)

like skin colour or basic morphology, genetics shows that the picture is far, far more complex.

WHAT ARE THE BIGGEST SCIENTIFIC MISCONCEPTIONS ABOUT RACE?

One of the really big misconceptions is the concept of racial purity. In the UK, we're seeing a resurgence of the far-right. All over the world, neo-Nazis and white supremacists are obsessed with genetics and ancestry testing. White supremacy is dependent on a notion of white or northern European purity.

Apart from the fact that biology has rejected the idea of race as a meaningful scientific terminology, the idea that there could be racial purity is just ahistorical, ascientific, it's an absolute nonsense.

There's been a weird emergence of this ancestry testing industry, and I think those kits amplify the sense that there is some kind of genetic essentialism which can be bound by nationhood. Being able to claim some loose membership to a long-gone people such as the Vikings is innocuous enough, but it's a position that is not scientifically meaningful. My concern is that they are effectively the same claims that actual white supremacists use, who take genetic ancestry testing as a demonstration of biological essentialism.

YOU RELATE THIS TO SPORT, AND HOW 'FACTS' FROM SPORTING HISTORY HAVE FUELLED PREJUDICE.

Within the confines of sport, we see regional differences in successes. Two examples that I go into are the 100-metre sprint in the Olympics, and long-distance running. There hasn't been a white man in the finals of the 100 metres since 1980. The Kenyans and the Ethiopians have won every long- and middle-distance and marathon race for years. If you're looking at these results, you're thinking, there's got to be something in this. Black men are better at sprinting, East Africans are better at long-distance running. The problem is the dataset is minuscule. So, 58 men have competed in the 100 metres final since 1980, which is a terrible sample size.

The second thing is that these are elite athletes at the top of human capability, and therefore are not representative of the populations from which they might have been derived. If success in certain sports wasn't primarily determined by cultural factors, then you would expect to see those same people who are good at explosive energy sports, winning in *all* sports where that biological type would predispose you towards success. Yet, take short-distance swimming. In the same period that there have been no white men running 100 metres, how many black people have competed in the finals of the 50-metre freestyle swimming in the Olympics? There's one. Cullen Jones got the silver in 2012 in the London Olympics. So, none of these numbers make sense.

All of this fits into a picture where people who aren't racist watch the Olympics and go, "Usain Bolt has won again, he's the fastest man who's ever drawn breath," which is probably true, "because it's in his genes. It's because it's in his ancestry." Now, one of those statements is partially correct, and the other is not. So, when someone says, "Well, you know, black people are better at sprinting," I want [my book] to have equipped people to be able to go, "Yeah… no."

SO MUCH OF WHAT WE USE TODAY HAS COME FROM RACISTS. CAN SCIENCE EVER BE RID OF RACISM?

That's a great question, one hopes the answer is absolutely 'yes'. I think it's perfectly reasonable and in fact necessary, to know our own history, and be completely honest about it. Genetics sort of underwrites all biological sciences now. The foundations of my field are closely associated with racism and race. If we forget that, we're in danger of repeating those mistakes.

Newton said that "we stand on the shoulders of giants", which is absolutely true – but we also stand on our peers' shoulders as well. We've got to remember that some of those giants were also living in eras where social norms were different, and racism was the norm. It's important to remember that scientists can also be awful people.

DR ADAM RUTHERFORD
(@AdamRutherford)
Adam is a geneticist, writer and broadcaster. He presents BBC Radio 4's flagship weekly *Inside Science*, and co-presents *The Curious Cases Of Rutherford & Fry* with Dr Hannah Fry.

Interviewed by **BBC Science Focus** ***editorial assistant Amy Barrett***

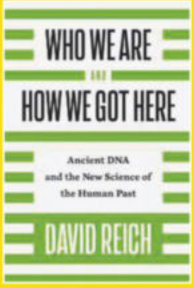
DISCOVER MORE

Subscribe to the Science Focus Podcast *and listen out for our full interview with Adam in an upcoming episode.*
sciencefocus.com/science-focus-podcast

GETTY IMAGES

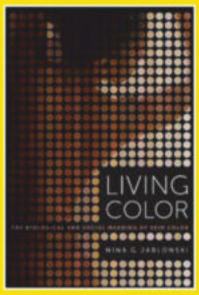
AUTHOR'S BOOKSHELF

My advice is always read everything that you can and with as much diversity as you can.



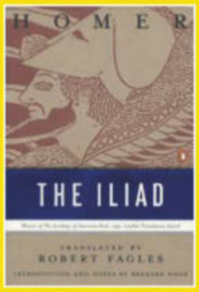
WHO WE ARE AND HOW WE GOT HERE
DAVID REICH
(£10.99, OXFORD UNIVERSITY PRESS)

David Reich's book on ancient DNA has been important to me.



LIVING COLOR
NINA JABLONSKI
(£25, UNIVERSITY OF CALIFORNIA PRESS)

This is an accessible textbook and it's focused on pigmentation. It is an outstandingly good book, and heavily influenced me.



THE ILIAD
HOMER

More than anything else, I recommend going back to the classics. I had to pick up *The Iliad* again in order to get some references and ended up devouring the latest translation by Emily Wilson. It's just one of the best books I've ever read.

RECOMMENDED

WHAT'S CAUGHT OUR ATTENTION THIS MONTH

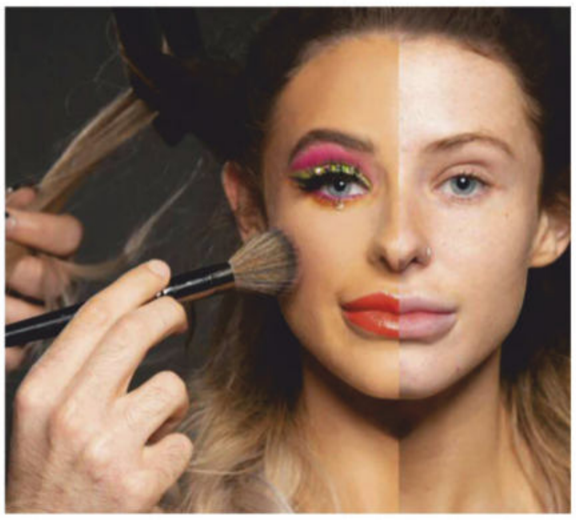
by **Amy Barrett**
EDITORIAL ASSISTANT

Perhaps it's because it's the month of love, but beauty seems to be on everyone's minds right now. But if you're thinking of buying, or asking for, makeup this Valentine's, you might want to watch ***Beauty Laid Bare*** on BBC Three first. This three-part programme sees four young adults investigate the cosmetic industry to find out the real price that the world is paying for our obsession with artificial beauty. Though the presenters' attitudes towards makeup seem initially superficial, they begin to question their own relationship with cosmetics when they attempt to get the truth from big beauty businesses on topics like animal testing, wages and recycling. Despite some of the shocking facts posed by ***Beauty Laid Bare***, it manages to provide a sense of hope and optimism. The proof that makeup can do good comes in the form of Shirley Raines, who offers makeovers to the homeless in downtown Los Angeles. Available on BBC Three from 2 February, it really is a must-see.

The BBC Radio 4 documentary series ***Art Of Now*** explores worldwide cultural issues and trends, and this month they are looking at aesthetics from a different angle. The episode on 18 February, sees lecturer and writer Vicky Neale offer a mathematician's guide to beauty by meeting the artists and mathematicians working together to redefine and innovate the art scene.

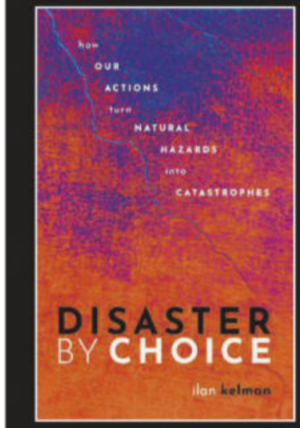
Make a note in your calendar to check out the events happening in your area this British Science Week (6-15 March). Most universities will have a programme for the festival, but you might also want to try running your own activity – why not gather friends and family one evening to take part in a Star Count (p90)?

> "Four young adults investigate the cosmetic industry to find out the real price we're paying for artificial beauty"



READING LIST

NEW BOOKS TO THUMB THROUGH



DISASTER BY CHOICE

ILAN KELMAN
£16.99, OXFORD UNIVERSITY PRESS

Just how 'natural' are natural disasters? Ilan Kelman argues they are a result of human actions. It's the choices we've made that turn natural hazards into widespread suffering and disaster. But we can change this. *Disaster By Choice* is dedicated to those who've suffered greatly, and praises those working to prevent the next hazard becoming a disaster.

QUA
LITY
LAND
MARC-UWE KLING

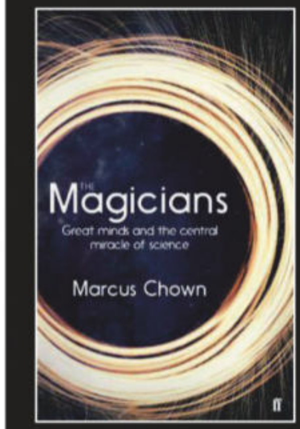
EDITOR'S CHOICE

QUALITYLAND

MARC-UWE KLING
£14.99, ORION

In Qualityland, life is optimised. There's no need for deliberation or confusion: your ideal mate is chosen for you, a personal assistant lives in your ear, and algorithms deliver packages to your door before you've even thought about purchasing.

This dystopian novel is entirely convincing as a possible future and is currently being adapted for TV by HBO, the producers of *Game Of Thrones*.



MAGICIANS

MARCUS CHOWN
£14.99, FABER & FABER

"The Universe has a mathematical twin," writes Marcus Chown, "but why it has such a twin is a huge mystery."

Magicians is the story of the scientists who write the Universe's rules as equations. Those who, using mathematics, predicted the existence of things such as black holes, subatomic particles, unknown planets and antimatter, before they were discovered.

THE BOOKS THAT MADE ME: ANTHONY DAVID

NEUROPSYCHIATRIST ANTHONY DAVID HAS HAD A LONG CAREER STUDYING THE MYSTERIES OF MENTAL ILLNESS. HIS NEW BOOK, *INTO THE ABYSS*, OFFERS FASCINATING INSIGHTS INTO THE COMPLEX, FRAGILE THING THAT IS THE BRAIN. HERE, HE TALKS ABOUT THE BOOKS THAT HAVE INFLUENCED HOW HE THINKS…

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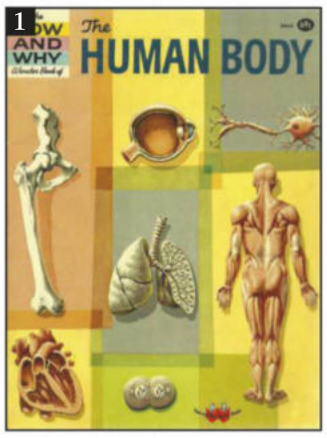

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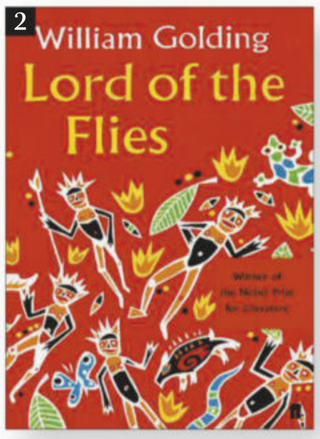

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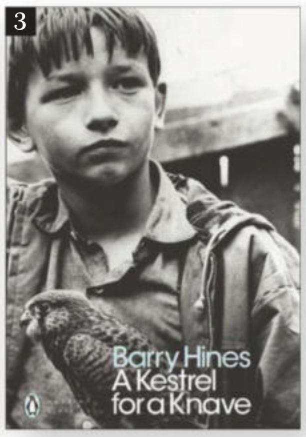

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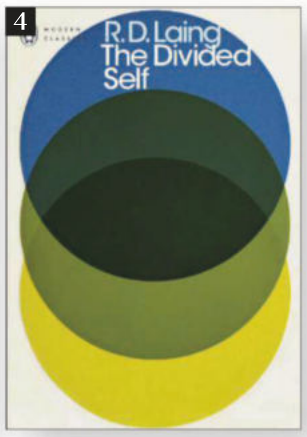

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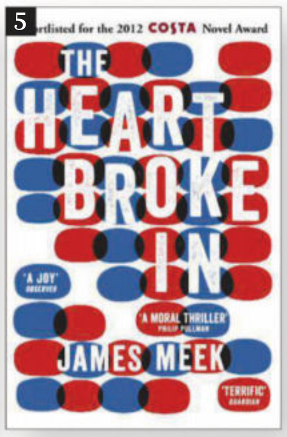

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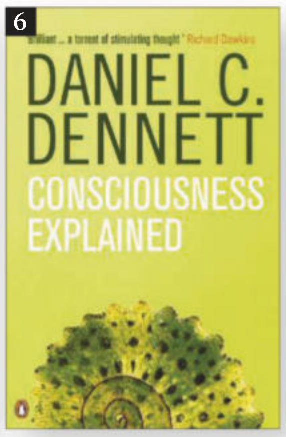


When I was around eight or nine, there was a whole series of *How And Why* books on different science and history subjects. It was the ***How And Why Wonder Book Of The Human Body*** that intrigued me. There were pictures of the skeleton and the muscles and the circulation, and I just couldn't get enough of it. From that age, I knew I wanted to be a doctor and study the human body.

English was the subject at school that I was least good at. Science seemed quite obvious and natural to me, but I think my struggle with English has been rewarding. There were two books that we studied at school, round about O Levels, that really made an impression. They were ***Lord Of The Flies*** by William Golding and ***A Kestrel For A Knave*** by Barry Hines. These were books where I suddenly realised that books could be powerhouses of huge ideas, moral dilemmas. In the case of *Lord Of The Flies* the dilemma is about the nature of humanity and good and evil, and for *A Kestrel For A Knave* it was all about social injustice and how we can promote change.

I read ***The Divided Self*** by R D Laing as a young student, probably just at the beginning of university, and this was really what switched me on to psychiatry. He wrote this book before he was 30, and it was a radical rethinking of psychiatry and particularly schizophrenia, the most severe form of mental illness. It was a very difficult, technical book, but it was revelatory. I since became a much more conventional psychiatrist, but I've never lost that sort of slightly radical edge that Laing had.

My next choice is completely different. It's a novel called ***The Heart Broke In*** by James Meek, and it's a wonderful story; it's a state-of-the-nation novel about Great Britain in the 1990s and 2000s. It's a great reflection on the country generally, but particularly the relationship between ordinary people and science. One of the characters in the book is researching a malaria vaccine, and it doesn't quite go as well as she'd hoped. An element of the novel is about funding for research and charities and how they can shape the scientist's approach and compromise their ideals. It makes the book quite unique.

I learnt so much editing *Insight And Psychosis: Awareness Of Illness In Schizophrenia*, obviously about the subject matter itself, but also how satisfying it is to bring together people from different disciplines who are all struggling with the same topic. That's something I think psychiatry's brilliant at. It was a great experience for me, and it has been a big part of my life as well.

My final choice is ***Consciousness Explained*** by Daniel Dennett. He's a philosopher, and incredibly knowledgeable about psychology and neuroscience. He shows how you can apply empirical knowledge in psychology to the great questions of the philosophy of mind. He's one of those writers that wears their scholarship lightly. It's a brilliant talent to be able to tackle these huge subjects and make them accessible without dumbing them down.

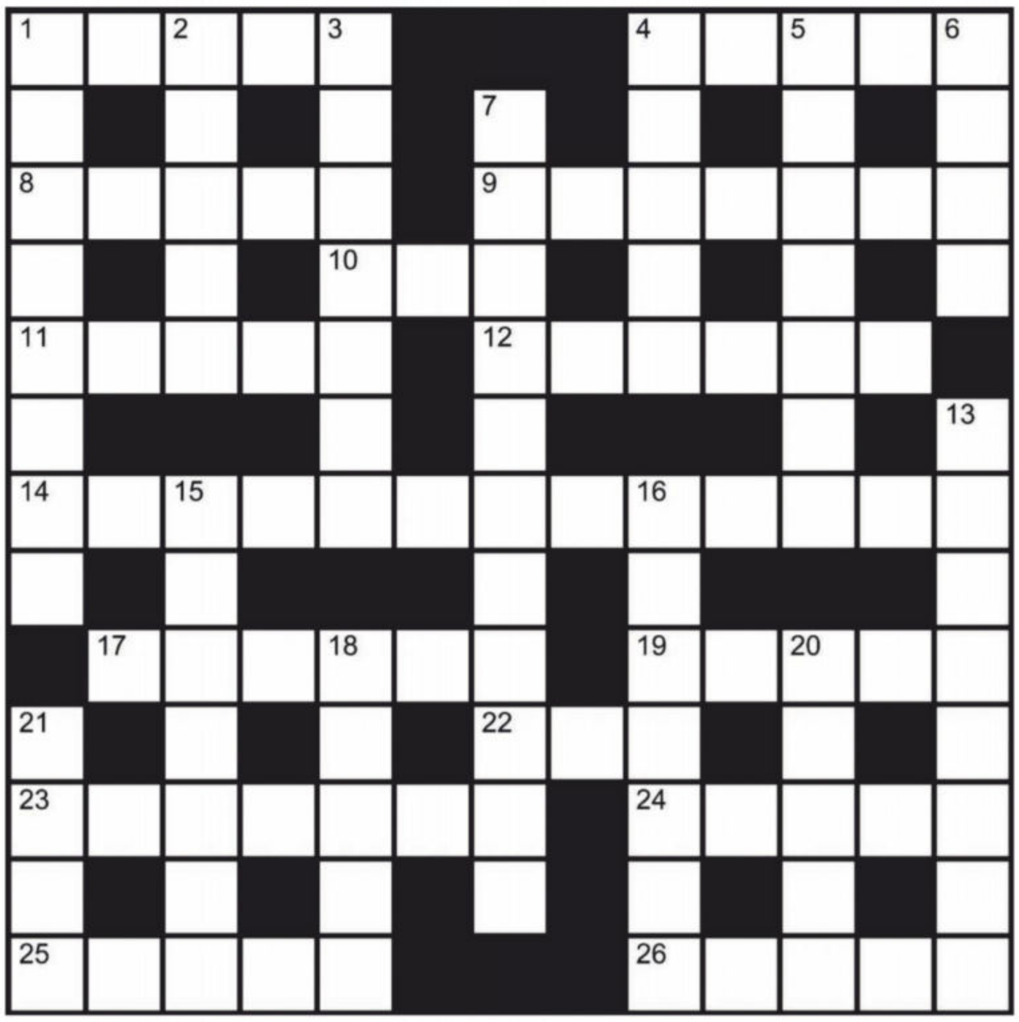
> "There were pictures of the skeleton and the muscles and the circulation, and I just couldn't get enough of it. From that age, I knew I wanted to be a doctor and study the human body"

by PROF ANTHONY DAVID
(@ProfTonyDavid)
Anthony is head of psychiatry at the Institute of Psychiatry, King's College London. He is a practicing clinician at the Maudsley and Bethlem hospitals. His latest book is Into The Abyss *(£14.99, Oneworld).*

BBC

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Directions on strange immunity agent (5)

4 Student of vision (5)

8 Embellish an entrance, removing nothing new (5)

9 Unaware, having left one out, that's evident (7)

10 Academic gets depressed without wife (3)

11 European name devised for invasive procedure (5)

12 Small, tiny, initially causing irritation (6)

14 Concert involving English queen and table that shows radioactivity (6,7)

17 After church, genuine breakfast (6)

19 Bank connection is a non-starter (5)

22 Heard second person was an animal (3)

23 Philosopher taking on part of the army (7)

24 Fish in the corner (5)

25 Accompanied by daughter in a particular dimension (5)

26 Fungus, when still seen around (5)

DOWN

1 Technologically advanced area needs time (5,3)

2 Travelling on her river (5)

3 Named organisation takes French article to be dull (7)

4 Aviator has change of heart to victory spin (5)

5 Support the eccentric visionary (7)

6 Having plenty of money, not initially rich (4)

7 Communicate with fellow to get small visual aid (7,4)

13 Cheese indulgence is most fleeting (8)

15 Diamonds come down from the country (7)

16 International group prepared for Ethelred, say (7)

18 Cope badly – hard time (5)

20 Follow mother in conviction (5)

21 Eject from small bench (4)

ANSWERS For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

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ARE WE GETTING ANGRIER?

The online world is full of outrage, hate and fake news. Is this seeping into the real world?

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Animal camouflage that doesn't stink.

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A SCIENTIST'S GUIDE TO LIFE

HOW NOT TO DATE A PSYCHOPATH

AS VALENTINE'S DAY ROLLS AROUND AGAIN, FORENSIC PSYCHOLOGIST **KERRY DAYNES** EXPLAINS HOW *NOT* TO DATE A PSYCHOPATH

PSYCHOPATH. SHOULD I WORRY?

If you're asking yourself whether or not you're dating a psychopath, then that in itself is telling you something. Your partner is unlikely to be a psychopath, but it could be a sign that you're dating someone you shouldn't be. Perhaps it's time to rethink your relationship.

HOW CAN I TELL?

Psychopaths lack empathy and are prone to antisocial behaviour. They're often impulsive, coercive and intense, but no two psychopaths are the same and there's no single sign to look out for. Look for clusters of behaviour that make you feel uncomfortable.

HOW LIKELY AM I TO BE DATING A PSYCHOPATH?

Most people who show these behaviours aren't psychopaths at all. They're probably just *****. About 1 to 3 per cent of the population are genuine psychopaths, but despite what the media portrays, few psychopaths are rapists or murderers. I work with criminal psychopaths, who do break the law, but most psychopaths aren't law breakers. We call them 'successful psychopaths' because they often end up with high profile jobs in areas like politics, business and the military. They can be charming; some more than others. One study showed that American psychopaths are more charming than Glaswegian ones! Psychopaths are prone to grand ideas and gestures. They can be intense and exciting to be around. The problem is that often, their gestures feel hollow because the day-to-day empathy is lacking.

CAN PSYCHOPATHS MAKE GOOD PARTNERS?

It's about what you're looking for. If you want to go out with someone who's successful, exciting and charming, but probably not the most sensitive or reliable partner, it's up to you. I think you'd be foolish to expect any long-term commitment from a psychopath.

ARE YOU LIKELY TO MEET A PSYCHOPATH ON AN ONLINE DATING SITE OR APP?

It's possible. There's certainly a psychopathic culture around internet dating. There are so many individuals to talk to online, it's easy to stop thinking of them as people and treat them badly.

The anonymity of online dating can make people feel that they're not personally accountable for their behaviour. It causes changes in key brain regions that are linked to aggression and poor decision-making, and may help explain why some people feel it's okay to be rude to others online.

WHAT'S THE BEST WAY TO DUMP A PSYCHOPATH?

Don't be frightened of dumping them. Most psychopaths are quite fickle. They look at relationships in terms of what's in it for them. Whether or not they're easy to dump depends on the value you have to them.

It could be that you dump them and they then move on to the next partner who they've been seeing behind your back for the last three weeks. You're free. **SF**

KERRY DAYNES

Kerry is an independent forensic psychologist and author. Her memoir, The Dark Side Of The Mind *(£7.99, Octopus), is out in paperback this month.*

Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Psychopaths can be charming, intense and exciting, but they lack empathy.

2

Don't be worried about dumping a psychopath. They probably won't care.

3

The majority of psychopaths are not lawbreakers.

ILLUSTRATION: JAMES MINCHALL

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